NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT FOR FISCAL YEAR 1983

HEARING

BEFORE THE

COMMITTEE ON LABOR AND HUMAN RESOURCES UNITED STATES SENATE

NINETY-SEVENTH CONGRESS

SECOND SESSION

ON

S. 2349

TO AUTHORIZE APPROPRIATIONS FOR THE NATIONAL SCIENCE FOUNDATION FOR FISCAL YEAR 1983

APRIL 15, 1982

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NATIONAL SCIENCE FOUNDATION AUTHORIZATION FOR FISCAL YEAR 1983

THURSDAY, APRIL 15, 1982

U.S. SENATE,
COMMITTEE ON LABOR AND HUMAN RESOURCES,
Washington, D.C.

The committee met, pursuant to notice, at 9:30 a.m., in room 4232, Dirksen Senate Office Building, Senator Orrin Hatch (chairman of the committee) presiding.

Present: Senators Hatch, Hawkins, and Kennedy.

OPENING STATEMENT OF SENATOR HATCH

The CHAIRMAN. The committee will come to order.

It is my pleasure to welcome you to this hearing of the Labor and Human Resources Committee to consider S. 2349, a bill to authorize funds for the work of the National Science Foundation for fiscal year 1983.

Our Nation's goals for the 1980's include sustained economic growth, improved competitive ability in international markets, a defense system to guarantee peace worldwide, and an enhanced quality of life for all Americans. These goals depend greatly on our overall capacity in science and technology. The patient efforts of our country's scientists have led to discoveries allowing us many freedoms, conveniences, and economic rewards.

Fundamental to these achievements is an understanding of nature and scientific phenomena. Before man could fly, he first needed to learn and apply the laws of gravity and aerodynamics. The exploration of these problems is basic research and is the principal mission of the National Science Foundation. Since 1950, when the United States was properly worried that we were falling behind our political and economic competitors in science, the National Science Foundation has been administering a comprehensive system of peer review and grants to the most promising research projects in our country. Awarded primarily through our higher education institutions, these grants have a twofold purpose: First, to advance our knowledge of certain scientific facts and applications; and, second, to assist in the training of students, who will be the principal investigators of the future.

Understanding the importance of this work to the revitalization of our economy and our national defense, the Reagan administration has recommended a nominal increase for NSF for fiscal 1983. It is our purpose here today to evaluate the administration's proposal for the Foundation to determine how it will effectively carry out U.S. science policies. Our considerations in this regard will be for the most part directed toward: One, the specific funding levels for each research directorate, keeping in mind our overall economic program; two, the need to address the problem of scientific and technical personnel and instruction; three, the encouragement of women and minorities to enter science professions; and, four, the role of the National Science Foundation in formulating national policies and accountability.

I would just like to add a word of clarification regarding the bill itself and our hearing's format. First, in the printed version of S. 2349, section 2(a) is incorrect. The total requested by the administration for NSF's research programs should read: $1,070,568,000. This amount, plus $2.2 million for special foreign currency, gives us a total for NSF of $1,072,768,000—an increase of 7.4 percent over the current plan.

Second, I would like to point out that our witnesses this morning were selected by a representative group of scientific and educational associations. The statements presented by Drs. Burbidge and Rutherford represent the broadly held views of our Nation's scientific community.

On behalf of the entire committee, I want to express appreciation to all of our panelists here today. I realize it is a considerable inconvenience for you to drop your activities for the day and fly to Washington, but your willingness to do so represents a sincere commitment on your part to help us do what is right for NSF, for scientific research, and for our country. The deliberations of the Labor and Human Resources Committee over the last many years on NSF legislation have been more complete due to your thoughtful participation and cooperation. Please accept our thanks for your insights.

At this point, we will insert in the record the statements of Senators Hawkins and Kennedy.

[The statement of Senator Hawkins and Senator Kennedy follows:]

PREPARED STATEMENT OF SENATOR HAWKINS

Senator **HAWKINS**. Mr. Chairman, I am pleased that we are holding hearings on the reauthorization of the National Science Foundation. Although it may appear unusual to markup a bill less than a week after the hearing, it should be remembered that we held hearings and a committee markup on this legislation last year and have extensively debated this issue. Due to a jurisdictional dispute between this committee and the Committee on Commerce, Science, and Transportation, the issues surrounding the reauthorization of the NSF, the level of Federal funding, and the allocation of that funding among the different scientific disciplines have been fully and extensively debated.

Since last year, I have noted a change in attitude concerning the National Science Foundation, which I believe is attributable to the extensive scrutiny of NSF. While last year reductions in funding for science education and behavioral and social sciences were recommended, I believe that the administration and the Congress are reassessing their positions on the allocation of funding for the National Science Foundation. We are realizing that NSF is virtually the only source of support for research in science education and that science education has a significant impact on productivity and national security. We are also realizing that little social and behavioral science research is characterized by the type of grant that get reported in the National Enquirer or earn Golden Fleece Awards.

For these reasons, I think that the year long delay in reauthorizing the National Science Foundation, has been beneficial because it has given us time to review the work of the Foundation in detail.

STATEMENT OF SENATOR KENNEDY

Senator KENNEDY. For over 30 years, the National Science Foundation has stimulated American scientific research and technological achievement. It has been the crucial partner in both expanding science education and supporting science research.

The National Science Foundation has been a primary supporter of basic and applied research; it encourages young people to enter scientific and technical fields; it keeps scientists aware of the constantly changing body of knowledge in their fields; and it offers the general public an understanding of how science affects every aspect of their lives.

This Nation faces great challenges in its struggle to regain economic strength and security; a vigorous and creative scientific community is essential to meet these challenges. We cannot afford to allow our national investment in research and development to decline while the Soviet Union's investment is on a constant rise.

We cannot afford to see fewer chemists, physicists, and biochemists trained in the next decade. We cannot afford to have the equipment and instruments in the universities and national research centers funded by NSF deteriorate because of cutbacks in those programs. As we analyze the proposals before us, we must take a broad view. We cannot look only at what dollar savings are claimed. We must also understand the impact of budget cuts on our industrial might, on our military capability and to our scientific progress.

The administration claims that its NSF budget for fiscal year 1983 provides for a small margin of 2 to 3 percent real growth for selected research programs. But this claim is based on the highly unrealistic assumption that the annual rate of inflation for fiscal year 1983 will be only 6.5 percent. A rate of inflation that CBO has called optimistic. It is clear that if the actual rate of inflation is even a little higher than the administration estimates, the fiscal year 1983 NSF budget will be forced to absorb real cuts in many research programs. In terms of constant dollars for the 2-year period, fiscal years 1981–83, the administration's proposed NSF budget for fiscal year 1983 represents an actual decrease of 6 percent.

The administration's NSF budget does more than just put the brakes on America's research and development. It cuts out all funds for the updating and upgrading of the knowledge base of science teachers and science curricula in our Nation's primary, secondary, and undergraduate schools. We will hear testimony today which conclusively establishes that now, more than ever, we need ongoing and active programs of science teacher and science curriculum rehabilitation. The administration's solution—simply creating a commission to study precollege math, science, and pre-engineering education—is not enough. While the Soviet Union, Japan, and West Germany maintain their programs of science education and development across all school age groups, the administration would put America on hold for at least a year pending further recommendations. This proposal is nothing less than a prescription to jeopardize America's competitive edge in the world economy.

Equipment obsolescence is a severe problem for university science and engineering laboratories. During the 1970's, equipment intensive fields—such as physics, chemistry, the life sciences, computer science and engineering—experienced rapidly escalating costs for maintaining existing laboratory facilities and for developing the newer, state-of-the art equipment.

According to one estimate, equipment replacement costs rose at an average rate of 4 percent above inflation during the 1970's. At the same time, Federal funds for research equipment and facilities declined sharply during that period. Few universities have the resources to offset the decline in Federal support. The problem of equipment obsolescence could have adverse consequences for industrial research laboratories that have, in the past, relied heavily on university laboratories for innovative instrumentation concepts.

Last year the Reagan administration deferred the $100 million laboratory rehabilitation program proposed by the Carter administration. This year the Reagan administration proposes no major new initiatives and relies exclusively on the Economic Recovery Tax Act of 1981, which establishes an increased deduction for manufacturers of research equipment who donate instruments to universities. Yet, there is little evidence that these tax provisions will have a substantial impact on laboratory rehabilitation. Congress must now take positive steps to address this critical need.

The social and behavioral sciences provide vital assistance in the resolution of critical economic and social policy questions.

I am deeply concerned by the administration's proposal for the social and behavioral sciences. Funding for these activities would increase by only 2.5 percent over fiscal year 1982 levels compared to the 8 percent 1-year increase in the total NSF budget.

The harm is even more dramatic in specific program areas compared to fiscal year 1981. The proposed fiscal year 1983 NSF budget represents a reduction of: 13 percent in the area of information sciences; 24 percent in the area of social measurement and analysis; 27 percent in the area of cognitive science; 28 percent in the area of political and policy sciences; and 33 percent in the area of economics and geography.

Finally, when compared to prerescission fiscal year 1981 levels, funding for research in the social and behavioral sciences declined by 41 percent.

This is the year that the President has designated the "National Year of the Handicapped," yet the administration proposes to eliminate the program on science and technology to aid the handicapped. It is inconceivable that the $1.6 million spent in fiscal year 1981 is this critical program area could possibly be considered ill spent. Nor is the administration's insensitivity limited to this one program, the only other NSF program with a primary focus on the handicapped—the minorities, women, and the physically handicapped program—is also zero funded for fiscal year 1983. The study of science and technology should be available to all Americans, and the benefits of science and technology should go to all Americans. The Congress must not turn its back on the needs of the handicapped by eliminating these important NSF programs.

Finally, I want to express my concerns about the situation of women and minorities in science and engineering. Almost a year and half ago, the Congress sought to expand the number of women and minorities pursuing careers in the sciences. With the passage of the Science and Technology Equal Opportunity Act, Congress recognized that too many talented women and minorities were being shut out of science and engineering because of factors unrelated to their ability to make an important contribution to the Nation's research community.

In January of this year, the NSF released a study showing that women's share of the science and engineering work force is less than 10 percent and that blacks represent less than 2 percent.

I am heartened that some women and minorities programs have been increased for fiscal year 1983 over fiscal year 1982 in the administration's proposed budget, but we must not forget that less than $9 million will be targeted for these programs, and that the minority institutions science improvement program would be decreased by 31.2 percent in fiscal year 1983 from its fiscal year 1982 levels in the proposed shift to NSF from the Department of Education.

The testimony today will assist the committee in understanding the full importance of the work of the National Science Foundation, in defining NSF's future priorities, and in documenting the direct linkage between our scientific and technological capacity and our Nation's future. I look forward to working with the chairman and other committee members on this vital program.

The CHAIRMAN. We will begin this morning by calling upon our National Science Foundation Director, Dr. John B. Slaughter, with whom I have a very cordial and good relationship. We will look forward to your testimony at this time, Dr. Slaughter.

We are also very happy to have Dr. Branscomb and Dr. Langenberg here accompanying you.

Please proceed.

STATEMENT OF DR. JOHN B. SLAUGHTER, DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. LEWIS M. BRANSCOMB, CHAIRMAN, NATIONAL SCIENCE BOARD; AND DR. DONALD N. LANGENBERG, DEPUTY DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. SLAUGHTER. Thank you very much, Senator Hatch. It is a pleasure for Dr. Branscomb, Dr. Langenberg, me, and senior members of the NSF staff to appear here this morning. We thank you for this opportunity—the National Science Foundation greatly appreciates the strong support it has received from the committee and from you personally—to present NSF's fiscal year 1983 budget and to discuss some issues critically important to U.S. strength in science and technology.

With your permission, I would like to provide an overview of NSF's plans for fiscal year 1983. I will comment briefly and then Dr. Branscomb will talk about two specific matters of great concern to science and the committee: science education and research instrumentation in the universities and colleges. I will conclude our testimony with a summary of the NSF budget request.

Let me begin by saying that the fiscal year 1983 budget request reflects the emphasis that the Reagan administration has given to support for fundamental research. It recognizes that a strong effort in fundamental research is important to the Nation's well-being.

The budget was put together with careful consideration of the National Science Board, NSF management and professional staff, and the academic and industrial communities.

In constructing the budget, we emphasized scientific excellence and promise to determine the priorities for fiscal year 1983. At the same time, we took steps to insure that the budget will maintain a broad base of support for all scientific and research disciplines.

We also kept in mind the potential for contributions to national goals from the projects supported by NSF. The Foundation, as in previous budgets, has the opportunity for playing a strong catalytic role in efforts to accomplish these goals.

The fiscal year 1983 budget is tightly constructed yet well balanced to address the research initiatives for which the Foundation is responsible. It is fully consistent with the President's economic recovery program, and it will maximize the gains from the scientific investments proposed.

As you pointed out, the fiscal year 1983 budget request totals $1,072.8 million, an increase of 7.7 percent, or $76.6 million above the fiscal year 1982 budget. Some special increases are included for the priorities identified in the physical sciences and engineering. The support for research in the social and behavioral sciences also is substantially increased above the fiscal year 1982 amounts.

With respect to research instrumentation, the budget proposes about $95 million, an increase of about 12 percent. And the programs designed to improve the opportunities and contributions of minorities and women in science and technology are significantly expanded in the fiscal year 1983 request.

In NSF's science education program, graduate research fellowships include some awards for minority graduate students in science and engineering.

An important initiative about which both Dr. Branscomb and I will speak is the establishment of the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology.

At this time I will ask Dr. Branscomb to speak on how the National Science Board helped to establish the fiscal year 1983 priorities on two special issues: scientific instrumentation in the research universities and colleges and NSF's program in science and engineering education.

[The prepared statement of Dr. Slaughter follows:]

Statement of

DR. JOHN B. SLAUGHTER
Director, National Science Foundation

Before the

COMMITTEE ON LABOR AND HUMAN RESOURCES

U.S. SENATE

April 15,1982

Mr. Chairman and Members of the Committee:

I am pleased to have the opportunity to appear before this Committee to discuss the Administration's proposed budget for the National Science Foundation for FY 1983. Seated with me are Dr. Lewis Branscomb, Chairman of the National Science Board, and Dr. Donald N. Langenberg, Deputy Director of the Foundation.

In my discussion, I will provide you with an overview of our plans for FY 1983. Dr. Branscomb will present additional information on several important matters, including the National Science Board Commission on Precollege Education in Mathematics, Science and Technology and on private sector involvement in upgrading university research instrumentation.

INTRODUCTION

The Foundation's budget request for FY 1983 recognizes that Federal support for fundamental research is critical to the Nation's well-being. The budget we are proposing is the result of careful consideration by the National Science Board, the Foundation's management and professional staff, and the academic and industrial communities that we serve.

In setting budgetary priorities, several criteria were used: scientific excellence and promise; maintenance of a broad base of support across scientific and research disciplines; potential for contributing to important national goals; and meeting high leverage opportunities and challenges. We believe that the Foundation's plan is tightly constructed, well balanced, and consistent with the objectives of the President's Economic Recovery Program, and would maximize the scientific gains from the investment.

The proposed budget for FY 1983 totals $1,072.8 million, an increase of 7.7 percent, or $76.6 million above the FY 1982 Current Plan. Let me mention some highlights.

- Reflecting the Adminstration's view of the high importance to the Nation of NSF's investment in fundamental research, there is an increase for research and related activities of about $71.1 million, or 7.3 percent, above FY 1982.*

- Within research, increases are provided in most areas. Special increases are provided for the physical sciences and engineering. In addition, the social and behavioral sciences have been substantially increased over the amount proposed for FY 1982 in the Administration's Revised Budget Request of last March.

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* These totals exclude a transfer of budgetary responsibility for icebreaker support from the Coast Guard to the Foundation's Antarctic Program.

- Research instrumentation and major equipment support in FY 1983 is estimated to receive $95.3 million, or 11.5 percent, more than in the FY 1982 Current Plan.
- Programs to enhance the contributions of minority and women scientists and engineers in research careers are significantly expanded, compared to FY 1982.
- Graduate research fellowships are continued within science and engineering education.
- An important initiative in science and engineering education is the establishment of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology.

Before I provide greater detail, Dr. Branscomb will commont on the role of the National Science Board in developing the FY 1983 priorities and on two special issues. There are, as this Committee knows, growing concerns over the adequacy of scientific instrumentation in the Nation's research universities and over the state of science and engineering education. Because of this and because of the interest of the National Science Board, I have asked Dr. Branscomb also to comment specifically on opportunities for encouraging greater private sector involvement in upgrading university research equipment and to discuss the very important initiative, the NSB Commission on Precollege Education in Mathematics, Science and Technology.

With your permission, I will ask Dr. Branscomb to speak at this time.

THE NSF ROLE

Dr. Branscomb has discussed some unique aspects of the Foundation's activities. Several other features also differentiate NSF from other Federal agencies.

- Several agencies support research related to their specific missions, but NSF alone has a mandate to promote the progress of all fields of science and engineering, through the support of fundamental research, and to advance the U.S. science enterprise as whole -- not just to support work in a few fields relating to a given agency.

- In FY 1983, NSF will provide about 17 percent of the Federal government's investment in basic research. Moreover, the bulk of the Foundation's awards -- some 83 percent in FY 1983 -- are expected to go for research conducted at the Nation's universities and colleges, thus not only producing research results, but also strengthening the ability of these institutions to develop the scientists and engineers we will need in the future.

- Among Federal agencies, NSF is the major supporter of some types of research; for example, ground-based astronomy. Its five National Astronomy Centers will provide, in FY 1983, the special and sophisticated instrumentation needed by about 1,000 astronomers to conduct their research.

- The U.S. Antarctic Program, a national effort, is managed and budgeted by the Foundation.
- The Foundation has experimented with encouraging industrial involvement in fundamental research. Its Small Business Innovation Program, for example, has been recognized by the Congress as providing a model for other parts of the Federal government. Of the six Industry/University Cooperative Research Centers "seed-funded" by the Foundation, one has become self supporting and another receives over 70 percent of its support from industry.

With this general background, let me now turn to our budget request and focus on features that have resulted from applying the criteria that I mentioned in my opening remarks.

PROGRAMMATIC HIGHLIGHTS

Mathematics and Physical Sciences (MPS)

The amount requested for the MPS Activity is $298.7 million, or 9.5 percent above the Current Plan for FY 1982. Beyond the continued strong support across all disciplines, Computer Research was selected for special emphasis because of a strong unmet demand both for new fundamental ideas and for trained scientists. We plan to make several more awards for experimental computer science facilities to go with those awarded in FY 1981 and FY 1982.

Engineering (ENG)

Support for the ENG Activity increases by $8.9 million, or 9.8 percent, from the FY 1982 Current Plant for a total of $99.7 million. (The transfer of the Strong Ground Motion Array Project to the U.S. Geological Survey is excluded from this level.) Mechanical Engineering and Applied Mechanics increases by 13.7 percent, and Electrical, Computer and Systems Engineering by 11.1 percent over the FY 1982 Current Plan in response to the challenging opportunities that these programs face in such rapidly developing fields as communications, intelligent machine systems, robotics, and chemical processing.

Biological, Behavioral and Social Sciences (BBS)

Since we appeared before this Committee to discuss the FY 1982 budget, an intensive review of the behavioral and social sciences by the National Science Board has been completed. Its findings have helped shape our FY 1982 Current Plan and our FY 1983 request for these fields. The Board, after completing its study, re-affirmed that these fields are an important part of the scientific enterprise and that NSF has a distinctive role to play in their support. Priority was set on research that enhances the objectivity of the social and behavioral sciences, improves the quality of the data collected, and provides critical analysis and interpretation of the phenomena observed.

The request for the behavioral, social and economic sciences is $32.3 million for FY 1982--an increase of 53 percent over the Amended March Request--and $33.1 million for FY 1983. Within those amounts, the program is balanced between (1) maintenance and development of key national data bases; (2) improvement of research methodologies; and (3) investigator-initiated projects for fundamental research.

Astronomical, Atmspheric, Earth and Ocean Sciences (AAEO)

Within AAEO, because of the scientific and economic significance of research on the structure of continents, priority emphasis on the earth sciences is continued, with a planned increase of $5.2 million, or 17.8 percent, over the FY 1982 Current Plan. Within the astronomical sciences, by closing some smaller facilities, such as two sixteen-inch telescopes at Kitt Peak, NSF will be able to keep all major instruments and facilities active in FY 1983. Another difficult decision has been made in the ocean sciences, where we will continue to upgrade ships and ship equipment at the expense of sea time for scientists.

Ocean Drilling Program(ODP)

Alternatives for the ODP have been carefully reexamined during the past year. In October, 1981, when the petroleum company participants decided to discontinue their part in the program, we discontinued planning for the Ocean Margin Drilling Program. However, there is a widespread consensus that scientific activity at ocean plate edges is important for improved understanding of both earthquakes and the formation and location of ore deposits. Moreover, to develop such information requires drilling studies. The 1983 budget contains funds for continuing the ongoing drilling program. However, the Administration is now considering whether to continue ocean drilling by modifying the GLOMAR EXPLORER. I will keep the Committee informed as this progresses.

U.S. Antarctic Program (USAP)

In his memorandum of February 5, 1982, the President reaffirmed the policy that NSF is to manage and operate the U.S. Antarctic Program so as to provide an active and influential presence in Antarctica, and that funding of the Antarctic effort is not to be at the expense of other Foundation programs. In addition, in fiscal year 1983, $13.4 million has been added to cover the cost of icebreaker operations which were previously included in the U.S. Coast Guard budget.

Scientific, Technological and International Affairs (STIA)

Under the STIA Activity, special funding attention is given in FY 1983 to cooperative research programs with technologically advanced Western European nations. Continuing past efforts to stimulate research interactions between industry and universities, the Industry/University Cooperative Research Projects and Industry/University Cooperative Research Centers programs will receive increased support. Moreover, the FY 1983 budget request expands opportunities for minorities and women to contribute more to the Nation in their scientific careers.

Mr. Chairman, I know that the problem of underutilization of scientific talent has been and continues to be of concern to you and your Commitee. Mr. Chairman, you stated in your additional views which amended the Committee report on the FY 1981 NSF Authorization Act, "that women deserve a sounder base from which to compete and that America cannot afford to sacrifice the ideas which may be forthcoming..." The Foundation strongly agrees with that view and we would make a similar statement about minority scientists and engineers.

Through the efforts of yourself and Senator Kennedy, particularly in your support for the the "Science and Technology Equal Employment Opportunity Act, the Nation has been made aware of the need to draw upon the untapped talent of women and minorities in science and engineering careers.

Our request for FY 1983 pays attention to this problem. Comparing FY 1983 to FY 1982, the Visiting Professorships for Women program will double, the Research Initiation for Minority Institutions will quadruple, and the Minority Research Initiation program will increase by almost one-half.

Science and Engineering Education (SEE)

Dr. Branscomb has already described the purpose and status of the NSB Commission on Precollege Education in Mathematics, Science and Technology. I would like to reemphasize several points. First, there is no question that science education at the elementary and secondary levels is facing severe problems, including declining numbers of students participating in science, declining achievement, low salaries for mathematics and science teachers, inadequate numbers and preparation of science and mathematics teachers, and archaic teaching equipment. Despite the recognition that problems exist, there is disagreement as to what the solutions should be. Moreover, delivery of precollege education is basically a responsibility of state and local governments. Under these conditions, the wisest course for the Foundation is to play a catalytic role; to help identify critical needs; to define and provide information on them; and to encourage state and local governments, scientific and professional organizations, private industry, and other Federal agencies to make appropriate contributions to resolving them. The purpose of the NSB Commission is to formulate strategies and an action agenda.

For FY 1983, the Foundation sees its role as supporting graduate fellowships in science and engineering, because the training they provide is immediately and directly related to the NSF research mission. Therefore, the FY 1983 request for science and engineering education is $15 million for graduate research fellowships, including $1.5 million for minority fellowships.

Research Equipment and Instrumentation

Much of today's research is instrumentation dependent, and there is agreement that much of research instrumentation now in university laboratories needs upgrading. Because instrumentation needs vary from discipline to discipline, each NSF research program has examined its equipment needs and adjusted its priorities to respond to the situation facing it. Increases in anticipated instrumentation expenditures range from 4.8 percent for the Antarctic program to 23.5 percent for Engineering. Also, although no explicit line item appears in the FY 1983 budget for support of research instrumentation for 2-year and 4-year colleges, the Foundation plans to continue to provide this instrumentation through its regular programs. Overall, NSF expects to spend $94.2 million for research instrumentation in FY 1983, up by $10.6 million, or 12.7 percent, compared to FY 1982.

The precise size of the instrumentation deficit is not known. Rough, but reasonable, estimates indicate that it is between $1.0 and $4.0 billion. The magnitude of the problem requires that various Federal agencies; the universities, themselves; state governments; and private industry help in meeting these urgent needs. Some steps in this direction have been taken. The Foundation, with the support of the Director, Office of Science and Technology Policy, convened an Interagency Group on Research Instrumentation to begin to explore a possible Federal response. Finding that the problem was widespread, the Group concluded that an approach involving interagency coordination would be preferable to a single program operating in one agency. The reasoning behind this conclusion, like that followed by the Foundation in its handling of the problem, was to insure the best possible match to the diverse needs of the various disciplines.

I should mention that NSF is developing a system of indicators on the status of university research instrumentation. And, as

Dr. Branscomb has already stated, the effects of the recently passed legislation providing tax incentives for instrumentation manufacturers to donate scientific equipment to universities are being closely watched.

CONCLUSION

Mr. Chairman, I would now like to summarize for the Committee some important features of the Administration's budget request for the Foundation for FY 1983.

The Foundation's budget is lean and meets the objectives of the President's Economic Recovery Program. It continues a commitment to high quality scientific and engineering research, provides support across all disciplines, and provides for real growth in some exciting and promising areas crucial to the Nation's future. Many of the brightest graduate students in science and engineering will receive support under Fellowships or research grants. Major special research facilities, including the oceanographic fleet and the National Research Centers, will continue to be used by scientists seeking new fundamental knowledge. Research in the Antarctic will be continued, and we will maintain important international cooperative research efforts. Innovative efforts to encourage research cooperation between industry and the universities will be maintained. Very importantly, we will expand our efforts to encourage research contributions by talented members of ethnic minorities and women.

Many difficult decisions have been faced in constructing the FY 1983 budget. I believe that a strong and well-balanced plan has been developed that will result in scientific and engineering progress and contribute to the Nation's well being. I urge your support of these very important programs.

Dr. **Branscomb.** Mr. Chairman, with your permission, I will submit my formal statement for the record and summarize it orally.

The **Chairman.** Without objection, we will put it in the record in its entirety following your oral presentation.

Dr. **Branscomb.** Let me begin by saying the National Science Board is pleased that the President appointed a distinguished biologist from Utah, Dr. Jay Vern Beck, to the Board. He was confirmed, I believe, last week, and he is on board with us. We are pleased to have him.

The **Chairman.** I am very pleased, also, as you know.

Dr. **Branscomb.** I would like first to comment on programs for women and minorities. Many people somehow get the impression that such efforts must be made in addition to the emphasis that the National Science Board gives to excellence in science. The Board does not feel that way about women's and minorities' activities. Indeed, the Board feels that equal opportunity is absolutely indispensable to excellence in science because talent occurs randomly in the population. Hard work is necessary, but it is no substitute for talent. We simply do not have any more talented people in this country than we need to put to work on the great challenges which face us. Therefore, the ability to challenge every young person and every adult who can contribute importantly to science and technology is, in the Board's view, an indispensable feature of national policy.

For that reason, the Board believes that every activity in which the Foundation engages should be conducted in such a manner as to maximize the opportunity for deserving women and minorities to participate, to be challenged, and to want to be a part of this national endeavor. We appreciate the interest that the committee has shown in this activity.

The Nation is, indeed, challenged on what I would regard as high ground. The country has enjoyed superior performance over the years in science and technology. But today, the economy is challenged by diligent and skillful competitors overseas who themselves feature technological bases for their economies. Given the nature of that challenge, it is no surprise that the scientific community and the engineering community feel they could do a lot for this country that constrained resources do not permit. However, I am not here today to complain about the budget; I am here to defend it.

I say that—even though the scientific community could always use more generous support—because the decisions the Congress faces in allocating the available resources and bringing the economy into proper shape are difficult. We should count ourselves fortunate if there is sufficient understanding throughout the Congress that this budget deserves of its full appropriation. In that sense, I am here with Dr. Slaughter to defend a carefully constructed budget.

I would like to say a word or two about the way the National Science Board participates in the process of developing the NSF budget, because our hand perhaps does not show clearly through the bare numbers of the tables.

The Board members try to understand as best they can—through their scientific experience and their contacts with scientists and engineers outside the Foundation—the key opportunities and priorities in science the Board establishes, as indeed the statute establishes, goals for the Foundation to contribute as much as it possibly can to the strength of American science and technology as well as the quality and sufficiency of scientists and engineers who are trained for careers in research, development, engineering, and production.

We feel it is the Board's mission to try to maintain the U.S. position as a leader in international scientific and technological endeavors. To date, the country has been successful in that endeavor, and I think the Board has contributed importantly to the success.

We do not believe that we can easily separate the mission of creating the knowledge and skills and tools needed for technology from the training of the people who will carry out the work in education and in industry. Indeed, the people are the heart of this process; they are the transfer mechanism from academic science to the economy to the industrial team. More importantly, it is the skill that they take to their work that creates the new knowledge and the new activities—not the bare documents, books, papers, and journals in which that knowledge is archived.

Therefore, the Board attaches a first priority to the long-range fundamental research capability on which all other technical activity rests. However, in parallel with it, the Board attaches a high priority to the human resources upon which the further progress in science and its effective use rests. Consequently, it is a well-considered policy of more than 30 years that the bulk of Federal Government support for science research should be conducted in educational institutions. In that manner the country gets both the maximal investment in human resources and a fruitful and innovative environment for creating knowledge.

When the Board approaches science education, it must be understood that our first priority is to promote the effectiveness of the educational system at the research level; that is, in graduate education and in the colleges and universities where research is conducted. Our second priority is to insure that the Foundation plays its proper role in understanding the health, status, and critical needs of American science and engineering education. In some cases those critical needs fall in areas which clearly are the Foundation's mission to pursue, and the Board attempts to pursue them. In other cases, it is clear that others have a better capability to address the problem—perhaps State and local governments, school boards, or even citizens.

Finally, the Board sees some specific high leverage areas in science and engineering education where significant improvement in educational outcomes might be achieved from limited investments.

The Board, having taken that view of its priorities in science education, asked the NSF Director to prepare an implementation plan, and jointly we determined that this was the right time to create a National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. We are almost ready to announce the Commission; I am sorry we did not make it by today, but I believe it will be only a few days before the Commission is launched.

The Commission will not be just another study commission; indeed, about 30 major studies are either under way or were recently conducted, and many deal specifically with mathematics and science education. The Commission certainly will take the benefit from those studies, but we hope and expect that the Commission will be action-oriented. We have asked its members to complete their work in 18 months, and we expect outputs in 6 months and at intervals thereafter.

The Board does not pretend that this effort is the only one, or perhaps even the most effective one, in the current resurgence of effort to rally the attention of the American public and its leaders to the school situation. But the Board does hope that it can assist other organizations in finding the proper activity for maximum leverage on the problems.

Let me say that I believe many Americans are concerned about their public school systems but probably do not appreciate the specific issues related to the teaching of mathematics. If students are discouraged from studying mathematics and science, or if mathematics and science are not available for them to study, or if the teachers who teach these subjects have not had the opportunity to obtain a full education in the disciplines they are teaching, then students may be deprived of the opportunity to participate in an activity which the Nation needs badly.

I have been personally shocked by some of the facts in this situation. A full third of the high schools do not even offer enough mathematics courses to permit students, if they took every course offered, to enter engineering college without remedial course work. In fact, about one-third of the entrants to engineering schools must take remedial courses to make up for deficiencies in their high school training.

Over 90 percent of the States now report shortages of mathematics teachers at the secondary level, and about a third of secondary school science teachers did not themselves major in science. Perhaps it will be more a source of concern to Americans if they appreciate that only about 6 percent of high school students take 4 years of mathematics, the normal minimum requirement for pursuing a technical career. Compared with that 6 percent, the corresponding number in the Soviet Union, in East Germany, in West Germany, and in Japan is nearly 100 percent.

We have taken much justifiable pride in the exceptionally good job that the best schools do and in the exceptionally fine tradition that we Americans observe for basing our democratic, social, and economic development on a universal system of education. But perhaps we do not realize the extent to which friendly competitors overseas—and nations perhaps not so friendly—have made a much more diligent national effort to build their competitive capability on an educational process unmatched in this country with respect to science and technology.

The issue is important. The Commission will have 18 private citizen members. Virtually all of them have technical backgrounds. Several distinguished scientists and engineers will participate, as will several distinguished lay citizens who are not themselves scientists but who are highly qualified to help the Nation with the problem.

Let me turn now to the question of instrumentation. I would like to emphasize that the problem we face in instrumentation is not just a matter of trying to rebalance the financial investment between the tools of science and the money for the talent to do the research. Instrumentation plays a vital role in the relationship between science and the use of science in the economy. In fact, when a scientist invents the tools with which he discovers a new phenomenon, it often is a short time before another scientist decides that he should start a small instrument business and make those instruments for other scientists to use. And it is often a very short time before one of those little companies realizes the instrument can be used not only to measure, but also to control; a new production tool has been created.

There is a close relationship between the tools of research and the tools of production. The instrumentation industry and the scientists concerned with improving instrumentation are important links in the relationship. That is why, as well as the fact that modern tools are required to do modern science, instrumentation has been a matter of great concern to the Board and to the Foundation for several years.

As Dr. Slaughter has pointed out, and I am sure he is prepared to discuss it at greater length, the Foundation is doing all it can to strengthen the investments in instrumentation. However, I would like to mention two other vehicles incorporated in the Economic Recovery Tax Act of 1981 that can, and I believe will, have at least some beneficial effect on this problem.

The first is section 221 which provides companies with a 25-percent tax credit for incremental R&D expenses. This provision really was intended to encourage R&D in commercial and industrial enterprises, but the tax credit is also available for incremental work carried out under contract to universities.

Overhead and capital costs are not eligible for inclusion as "qualified research expense." Therefore only 65 percent of the contract costs for contracted-out research is eligible for this tax credit, a figure that is designed to approximate the proportion of qualified research expense to gross research expense.

A simple calculation suggests that a firm in the 46-percent tax bracket would pay only 38 cents out of each dollar for a project at a university involving the acquisition, let's say, of a piece of instrumentation or the conduct of a piece of work.

It is too soon to tell how much stimulation to private sector R&D section 221 will provide or how much universities might share in the growth. I personally believe that Congress might want to consider looking again at the 65-percent factor applied to contracting out R&D in order to provide a substantial incentive to perform work at universities. Companies might be given extra encouragement to do some of that incremental R&D in the university sector, but I am sure Congress will consider it as the effectiveness of section 221 is assessed.

The other provision is section 222, intended specifically to encourage equipment donations by firms to institutions of higher education. The tax benefit really rests in the fact that the section permits the firm to deduct up to twice the base manufacturing cost, rather than only the manufacturing cost—the previous allowance.

Now, the firm may also deduct half of the difference between the sales price and the manufacturing cost, with a limit of twice the manufacturing cost.

This particular feature is being studied carefully by firms today, and some activity is already beginning; I believe we will see more. We do need additional clarification from Treasury regulations, and the Congress may want to examine this section to see whether legislative adjustments are needed. I say that because of three features of this particular provision. One is that the property must be used for research or experimentation or research training. While the legislative history is clear that research training may include training undergraduate as well as graduate students in the physical and biological sciences, it might be useful to make it clear in legislation that both types of training are covered.

Second, there is a restriction to use for research in the physical and biological sciences. Perhaps there should be some clarification to insure the section covers computer science, as well as the fields such as mathematics, biology, engineering, and other disciplines that are specifically included by the legislative history.

Third, to the extent that this is a relevant issue in secondary school science education, some attention should be given to section 222's restriction to institutions of higher education.

Now let me make a more general comment on industrial support of university research. There is today a great deal of activity and interest in the industrial community; universities do need help and industry does depend upon a vigorous research base for its own competitiveness. I think we can expect private industry to step forward and help in the university areas close to the cutting edge of industrial technology. Such interest can be seen today in the semiconductor integrated circuit activities at six or eight universities. A new program of the Semiconductor Industries Association will provide support to universities for that kind of work.

Such activities are an important adjunct to what Government has done in the past, but they do not relieve the Government of the role of supporting the basic and fundamental research base upon which that work rests. In fact, the demands ultimately will be increased for NSF support of the infrastructure as the universities become better equipped to participate with industry in the cutting edge of the technology revolution.

[The prepared statement of Dr. Branscomb follows:]

STATEMENT OF
DR. LEWIS M. BRANSCOMB
CHAIRMAN, NATIONAL SCIENCE BOARD
BEFORE THE
COMMITTEE ON LABOR AND HUMAN RESOURCES
U.S. SENATE
APRIL 15, 1982

Mr. Chairman and Members of the Committee,

I am Lewis M. Branscomb, Chairman of the National Science Board and Vice President and Chief Scientist of the IBM Corporation.

It is my pleasure to appear before you this morning to discuss the role played by the National Science Board in the development of the fiscal year 1983 budget for the National Science Foundation, the activities of the Board in rethinking the role of the Foundation in science and engineering education, and the role of both the public and the private sectors in providing research instrumentation.

But, first, I want to make a brief observation on another question of deep interest to this Committee--the participation of women and minorities in scientific and engineering careers. The National Science Board places a very high value on excellence in science. All our experience shows that discoveries cannot be planned, that trying hard is not a substitute for talent, that natural ability, motivation, and opportunity are the recipe for scientific excellence. We equally firmly believe that natural ability in mathematics and science is distributed randomly throughout all elements of our population. Unhappily, some of our youth, especially young women and minorities, are often discouraged from pursuing scientific careers. And opportunity for those careers does not always follow ability and motivation alone.

The consequence of these facts is that the excellence of our science inevitably suffers if we fail to give every rare talent the opportunity to prove itself. Equal opportunity is not counter to a focus on excellence; it is indispensible to it. Thus, it is appropriate that all the programs of the Foundation be conducted with this fact in mind. Quite apart from the matter of fairness, our country simply does not have enough bright, scientifically inclined youngsters for us to afford to deprive a good education, high motivation, and career opportunity to any of our citizens. We appreciate the interest of this Committee in these issues.

Let me now turn to the role of the National Science Board in development of the fiscal year 1983 budget for the National Science Foundation.

The fiscal year 1983 budget states that Federal responsibility in R&D activities relates both to Federal needs, such as defense, and to national needs, where the Federal Government helps to assure the strength of the economy and the welfare of its citizens. Two main responsibilities in this latter area are (1) providing a climate for technological innovation and productivity growth, which in turn encourage private sector R&D investment, and (2) direct research support when there is substantial prospect for significant gain to the Nation, but where the private sector is unlikely to invest adequately.

The second responsibility--direct support of research where the private sector may under-invest--is carried out in many agencies but especially in the programs of the National Science Foundation, where research is supported at the forefront of knowledge across all fields of science and engineering. Our goal is to assure U. S. scientists and engineers broad opportunities for excellence and leadership.

The National Science Board is charged by the Congress with a concern for the health and vitality of America's science and engineering capabilities. Working with the Director's executives and staff, we have spent a large fraction of our time over the past year attempting to balance priorities for NSF's research programs in the face of the very real problems caused by economic conditions and resulting budget stringencies. We are convinced that further advances in science and engineering knowledge and the technical vitality of people with these skills are the cornerstone on which our military and economic security rest. Since we cannot as a country afford to pursue all promising scientific and technical avenues at once, the Board, with the Director as an active participant, has allocated our necessarily limited resources to maximize the return to our scientific capabilities and thereby to the Nation. Let me describe this process.

Last winter and spring, Board members had a series of formal and informal discussions with the Director and Assistant Directors about priorities in the program areas for which they are responsible. These discussions were informed by the flow of advice we get from scientists and engineers in the field--through NSF advisory committees, through meetings and telephone calls, and through our own participation in developments in the various fields with which each of us is conversant. Board members and Foundation staff alike consider it an important part of their jobs to be open to input from the scientific community in a variety of forms, for priority setting in fundamental research is largely a matter of informed good judgment.

The Foundation and the Board must work within the context of overall budgetary policies decided by the Administration and the Congress. Last spring, as you know, the Administration requested changes in several parts of the Foundation's budget, as part of its strategy of reducing the budget in light of the Nation's economic situation. The Board's role in this case was one of assisting the Director by providing policy guidance.

In its policy paper of March 29, 1981 (which I sent to you at that time) the Board agreed that in the short term the National Science Foundation must focus the available resources on the task of contributing as much as possible to the strength of American science and technology; the quality and sufficiency of scientists and engineers educated for careers in research, development, and engineering; and maintenance of the U.S. position as a leader in international scientific and technological endeavors. Thus we put high priority on the key elements of our central mission, which we conceive to be support of science and engineering research performed primarily in academic environments to optimize both educational and knowledge benefits from a single investment. This priority continues in the proposed FY 1983 budget, and I urge your support of both the level and distribution of that budget. It includes increases for support of scientific and engineering research, thus contributing to NSF's unique role in keeping the sciences strong. It focuses on the educational matrix within which research is performed and future researchers are produced.

Well-trained and highly-motivated scientists and engineers are central to increasing our Nation's potential for growth and increased productivity. The source of these individuals lies ultimately in the primary and secondary education system of this country, and here there is less consensus on the proper role of the Federal Government.

During the past year, the National Science Board considered how the Foundation might carry out its responsibility under the National Science Foundation Act to "...recommend and encourage...national policies for the promotion of...education in the sciences" and "...to initiate and support...programs to strengthen...science education...at all levels."

The Board agreed on three appropriate priorities. Highest priority was assigned to research-level education, and this is reflected both in the continued graduate fellowship program in science and engineering education and by the research supported throughout the Foundation, with its intimate connection between graduate education and research. Secondly, the Board agreed that the Foundation should continue to play a role in identifying critical needs in science and engineering education, including needs for which it may not bear the primary responsibility. These activities may encourage other agencies, state and local governments, and private organizations to evaluate and meet those needs. Finally, the Foundation can intervene in selected high-leverage areas where significant improvement in education outcomes is possible with limited investment. The Board asked the Director to generate a plan for implementation of this policy framework and he did so. (Both these documents were sent to you in September.)

One area where the Foundation can play a leadership role, though states and local communities have primary responsibility, is in precollege education in mathematics and science. Many of us in industry are concerned that the future availability of qualified scientists, engineers, and technicians will be jeopardized by the decline in high school enrollments in science and mathematics, and declining quality of such instruction. Although there is an emerging consensus that something must be done to change this situation, there is less consensus about the proper role of the Federal Government, or of the Foundation. Under the circumstances, the Board concluded it must find a way to engage the Nation's scientific community in local activities to establish a stronger base of secondary school graduates with appropriate science, engineering, and math backgrounds from which to draw future generations of scientific and technical people. As a result, at its January meeting the National Science Board approved the establishment of a Commission on Precollege Education in

Mathematics, Science, and Technology. We hope to announce the membership of the Commission soon.

The Commission is not just another government commission and will not simply "study" the problems in precollege mathematics and science educations. There have, in fact, been about thirty major studies of the current situation in secondary school education, many of which focus on the specific deterioration of mathematics and science instruction. Just a few of the facts are enough to motivate any citizen to be seriously concerned. Only a third of all high school students ever take a course in math beyond the tenth grade. A full third of our high schools do not even offer enough mathematics to permit any of their students to gain entry into an engineering college without taking remedial courses, and in fact, about one third of the entrants to engineering colleges do take such remedial courses. Over ninety percent of the states now report shortages of mathematics teachers at the secondary level, and roughly a third of the secondary school science teachers did not themselves major in science.

The contrasting figures for Japan, Russia and Germany (both East and West) are equally staggering. Over a period of time, this difference will surely tell in industrial productivity, perhaps even in our defense posture. It will surely tell in the quality of preparation given our young people for living in a highly technological world.

The National Science Board is initiating the Commission not for the purpose of studying the problem, but to do something about it. The Commission will have about seventeen private citizen members and will be properly supported by staff and expert subpanels. Its duration is planned to be eighteen months.

We hope that major engineering and science professional societies, whose members number in the hundreds of thousands and reach into virtually every school district, will cooperate with the Commission to put their members to work on a grassroots effort to understand and begin to rectify the situation. We expect to come out of the Commission's work with a clear and justifiable role for Federal agencies such as the National Science Foundation, for the private sector, and for citizens everywhere.

Let me now turn to the question of instrumentation. This issue is more important than the contribution to research productivity that modern instrumentation can provide. The fact is that the tools of science and the tools of production are linked by the processes of discovery and innovation, each contributing to the other. Leading edge scientific instrumentation is an essential link in the evolution of new scientific ideas to exploitation of these ideas in the Nation's technology. The National Science Board addressed this point in our policy statement of March 1981, which noted that keeping university equipment at the cutting edge sparks both innovation and productivity improvements in American industry broadly.

Thus, the policy of the Board goes beyond balancing the Federal investment between facilities and talent for research. We seek to keep vital the roots of invention of new instrumentation for science, the rapid development of these ideas by private companies, large and small, and the evolution of the researcher's tools into the design and production tools of industry.

To this end a close collaboration among our university and industrial laboratories is essential. The Economic Recovery Tax Act of 1981 contains two provisions intended to encourage industry to share its instrumentation and knowledge with universities to their mutual benefit.

First, Section 221 of the Act provides a 25 percent tax credit for incremental R&D expenses. The credit equals 25 percent of the amount by which qualified R&D expenses during a year exceed the average of the previous three years. Qualified R&D expenses for in-house research include the wages of researchers and direct support personnel, the cost of supplies, and payments for the lease of equipment. Thus overhead and capital costs are not eligible for the credit (although the company's capital equipment costs may qualify for the investment tax credit). Qualified research expenses for research contracted out are 65 percent of the contract cost, a percentage designed to approximate the ratio of wages, supplies, and leased equipment to the total research cost.

This provision could and should be used by private firms to collaborate with colleges and universities and improve their instrumentation. For example, if a firm sponsored a university research project involving the purchase of a centrifuge, the cost of the centrifuge would be fully deductible as a research expense to the firm. Furthermore, 65 percent of the centrifuge's cost would be included as "qualified research" and would count in computing the amount of incremental research eligible for the 25 percent credit to the firm. Thus, if the centrifuge were part of the firm's incremental research and the firm were in the 46 percent tax bracket, the firm would pay for only 38 cents out of each dollar of the cost of the acquisition of the centrifuge by the university. If the same research were conducted in-house at the same gross expense, the centrifuge would cost the company a net after tax cost of 54 cents out of each dollar, minus the tax benefits of depreciation and investment tax credit. It is probably too soon to tell how much stimulation to private sector research and development investment will result, and how much the universities might share in the growth.

Section 222 can be even more valuable in encouraging firms to assist in updating equipment at colleges and universities. After the passage of Section 222, contributions of equipment to universities entitle the firm to a larger tax deduction if certain conditions are met. For example, if a firm donates a new centrifuge that costs $100 to make and sells for over $300, the tax deduction would be only $100 under the old law but $200 under Section 222.

In order for a firm to receive the increased donation, the gift must be new equipment that is constructed by the firm and given without strings attached to an institution of higher education primarily for research purposes. The firm and the institution must have a written agreement that the equipment will be used in the U.S. for research in the "physical or biological sciences." These conditions also involve some uncertainties that must also be resolved by Treasury regulations. For example, the very term "physical or biological sciences" must be interpreted or extended to include mathematical and engineering sciences at a minimum. The issuance of regulations now being developed that reduce or eliminate uncertainty and guide firms in the proper use of Section 222 will be beneficial to American science and technology.

Many firms are studying ways to use these provisions to improve and update the scientific instrumentation used by our country's colleges and universities, but the extent of their effect is still unknown. Increased private sector support will help, at whatever level it may be available. In addition to the equipment itself, relationships between industry and universities will be strengthened as industry develops an improved appreciation for the talents of universities and university faculty and students learn about interesting research problems important to industry.

The Foundation should and will seek to encourage private companies to expand their participation in university research. These tax provisions will surely help. But we cannot realistically expect the obsolescence problem to be solved in this way alone. We must also encourage the universities to share expensive facilities, to avoid the temptation to under-invest in equipment as a fraction of project cost, and to find innovative ways to capitalize new equipment acquisition with non-Federal funds.

The National Science Board will do everything it can to help the Foundation leverage its resources to assist with needs for research instrumentation and equipment and to promote university-industry cooperation. We are nearing the completion of a Board report on university-industry research relationships that we hope will contribute to understanding and enhance productive interaction between universities and industry. The Board also supports the development of mechanisms by which the Foundation can actively interact with industry in the provision of equipment to universities and colleges and has recently asked its Planning and Policy Committee, in conjunction with the Director, to develop a policy of direct collaboration with potential equipment donors, for future Board consideration and approval. We are excited by the possible new avenues for enhanced collaboration.

I am pleased to have had the opportunity to present these views, Mr. Chairman, and would now like to turn back to Dr. Slaughter.

The **Chairman**. Thank you so much, Dr. Branscomb.

Dr. **Slaughter**. Thank you, Dr. Branscomb.

Mr. Chairman, I merely want to complete my part of the testimony by explaining the context in which the NSF budget was developed and presented to you.

As you know, NSF is the only Federal agency whose mission is to promote progress in all fields of science and engineering through the support of fundamental research. In fiscal year 1983, NSF will provide about 17 percent of the Federal Government's investment in basic research. Some 83 percent of our NSF funds support research in the universities and colleges. NSF is very proud that its programs not only contribute to research results, but also help to develop the scientists and engineers needed for the future.

The Foundation is also a major supporter in several areas of research. For example, NSF is the principal, almost the only, supporter of ground-based astronomy in the United States. The Foundation does so in part through the support of 5 national astronomy centers which provide research opportunities for more than 1,000 astronomers.

NSF also is responsible for the national efforts in Antarctic research, and it has recently expanded its efforts to encourage industrial involvement in fundamental research. The Foundation's small business innovation program, for example, is a model for several other Federal initiatives.

Six industry-university cooperative research centers have been established by NSF. All have received seed money from the Foundation. All ultimately are expected to be fully supported by industrial organizations. One of the centers is now self-supporting, and another receives more than 70 percent of its funds from an industrial consortium.

Let me mention quickly some highlights in each major area of the Foundation's program. For example, the mathematical and physical sciences activities are to be funded at $298.7 million, an increase of 9.5 percent above the fiscal year 1982 plan, the increase means real growth for research in the mathematical and physical sciences. NSF will emphasize in this funding greater opportunities to develop fundamental training of scientists in critical areas such as computers. The Foundation expects to make an increased number of awards for experimental computer science facilities, continuing to augment those funded in fiscal years 1981 and 1982.

For engineering research, the budget request is increased about 9.8 percent to provide real growth of programs in mechanical engineering, applied mechanics, and electrical, computer, and systems engineering. The Engineering Directorate also will emphasize communications, intelligent machine systems, robotics, and chemical processing—all critical to the problems of manufacturing and productivity in this country.

Let me mention two categories, the behavioral and social sciences, disciplines that have been under review by the National Science Board during the past year. The Science Board reaffirmed the importance of the behavioral and social sciences as integral parts of the National Science Foundation program and emphasized that priorities should be assigned to research that enhances the objectivity of the social and behavioral sciences, improves the quality of the data collected, and provides critical analysis and interpretation of the phenomena observed.

Consistent with the Board's views, the budget request for the behavioral and social sciences shows a 53-percent increase above the amount, proposed in the March 1981 request for fiscal year 1982. The total for fiscal year 1983 is $33.1 million. I should add that the fiscal year 1982 budget for behavioral and social sciences was amended in mid-year from $21.1 million to $32.1 million. Consequently, in fiscal year 1983 NSF essentially will continue the program at the amended level for fiscal year 1982. The program will be concentrated on the maintenance and development of key national data bases, improvement of research methodologies, and investigator-initiated projects for fundamental research.

In astronomical, atmospheric, Earth, and ocean science activities, the emphasis in fiscal year 1983 will be on improved understanding in the Earth sciences. NSF plans an increase of $5.2 million in the Earth sciences program, or 17.8 percent above the fiscal year 1982 current plan.

In the astronomical sciences—I mentioned earlier that the Foundation is essentially the sole supporter of research in ground-based astronomy—we have made every effort to maintain these major facilities critical to the program's future. It will be necessary to close some smaller telescopes, but all major instruments and facilities will be maintained in fiscal year 1983.

NSF also intends to continue to upgrade the academic research ships, ship equipment and facilities for the oceanography program. The amount of sea time available to scientists will be reduced slightly in order to keep those facilities ready for first-rate research.

The support of ocean drilling activities for some years, has been an important part of NSF's program. Last year, as you recall, the Foundation proposed an ocean margin drilling program involving the participation of several oil companies. In October 1981, the companies said they could not continue in the program. The Board and NSF management decided to discontinue the ocean margin drilling program.

However, NSF recognizes that much fundamental research must be conducted at the ocean plates if the understanding of earthquakes and of the formation and location of ore deposits is to be improved. The fiscal year 1983 budget proposes to continue investigations of ocean drilling, including the possibility of modifying the Glomar Explorer as an improved ocean drilling platform. We will keep the committee informed of the project plans.

Last February, the President reaffirmed the policy that the National Science Foundation to manage and operate the U.S. Antarctic program to provide an active and influential presence in Antarctica, and that funding of the Antarctic effort not be at the expense of other Foundation programs. We are moving ahead in consonance with the President's statement. There is a $13.4 million addition to the budget for the Antarctic program, a transfer from the U.S. Coast Guard of necessary funds to support icebreakers so essential to operations in that part of the world.

The scientific, technological, and international affairs activity includes several efforts of critical importance to the country. For example, the cooperative research program with technologically advanced Western European nations will continue to receive emphasis in fiscal year 1983. And the industry and university cooperative programs—among them are the cooperative research centers that I mentioned earlier and the cooperative research projects involving scientists from universities and industry in joint, high-quality, fundamental research programs—will receive continued emphasis in the coming year.

Mr. Chairman, we know of your strong interest in increasing the employment of existing scientific talent. Both you and Senator Kennedy have addressed this matter in the Congress. The Foundation strongly agrees with both of you, and particularly, Mr. Chairman, with the statement you made on the 1981 authorization. The statement said, "* * * women deserve a sounder base from which to compete and * * * America cannot afford to sacrifice the ideas which may be forthcoming * * *." We can expand that statement to include minorities. It is a rallying cry for NSF efforts to improve opportunities for women and minorities in science and engineering.

The budget request for fiscal year 1983 calls attention to this matter. The visiting professorships for women's programs will be doubled, the research initiation for minority institutions program, will be quadrupled, and the minority research initiation program will be increased by almost 50 percent.

Dr. Branscomb has described the Foundation's activities in science and engineering education. I would like to reemphasize briefly several points.

There is no question that science education in the elementary and secondary schools is facing severe problems: declining numbers of students participating in science, declining achievement in science and mathematics, lack of rewards for teachers of mathematics and science, inadequate numbers of new science and mathematics teachers, and archaic teaching equipment.

Everyone agrees that there are problems. It is difficult, however, to develop a consensus on what solutions should be pursued in order to address the problems.

Moreover, it is complicated because precollege education is largely a reponsibility of State and local governments. We need to determine the wisest role for the Federal Government, and particularly the wisest role for the National Science Foundation.

This is a task in which the Foundation can play a critical catalytic role. And that is one of the reasons why we have taken steps to establish the National Science Board Commission on Pre-College Education in Mathematics, Science, and Technology. One of the proposed Commission members is in this room—the distinguished professor of chemistry from the University of Utah, Dr. Robert Perry. He is a good example of the persons who will participate in the Commission's work.

For fiscal year 1983, the Foundation's budget requests $15 million for the program of graduate fellowships in science and engineering. Included in that $15 million is $1.5 million oriented toward fellowships for minority students.

Dr. Branscomb also has discussed research instrumentation and major facilities. I will simply underline the Foundation to increase the program to about $95 million for research instrumentation. The request certainly does not begin to address the magnitude of this problem, estimated at between $1 and $4 billion required to equip the research universities with the kind of instrumentation necessary to maintain first-rate research.

Dr. Langenberg, the Deputy Director of the Foundation, has chaired an interagency committee to address the problems of research instrumentation. We are confident that we will be able to continue that effort, and I hope we will be able to come before you later with a program that begins to address that problem somewhat more aggressively.

Mr. Chairman, I think we have demonstrated today the priorities and levels of emphasis included in NSF's fiscal year 1983 budget. We believe it is a budget well balanced to address the primary scientific and engineering research programs. As Dr. Branscomb said, we also believe it is a budget to defend so that further erosion can be avoided in this country's research efforts.

We will be pleased to answer any questions that you or members of the committee may have.

The CHAIRMAN. Thank you so much, Dr. Slaughter.

You have stated in your testimony that approximately $95 million will be allocated or designated for instrumentation equipment. How do you allocate these funds among directorates? What type of mechanism do you have to keep track of what is spent in this area?

Dr. SLAUGHTER. Since as Dr. Langenberg has been primarily responsible for NSF instrumentation activities, I will ask him to respond.

Dr. LANGENBERG. Mr. Chairman, I am happy to report that NSF has reviewed its estimates for instrumentation and equipment in fiscal year 1983; the Foundation is requesting almost $110 million for instrumentation and equipment, rather than the $95 million reported earlier.

The level of instrumentation, the type of instrumentation, and the magnitude of instrumentation required for research in a scientific field depends a great deal upon that field. It will come as no surprise to you that NSF provides few funds for equipment in grants to mathematicians. But in chemistry, physics, materials and Earth sciences, and astronomy, demands for equipment are high.

We have determined that each of the NSF divisions responsible for a given discipline ought to be able to balance the needs for instrumentation and the needs for other types of research support in a way that will best suit the scientific goals of that discipline. NSF does not explicitly identify and set-aside instrumentation funds in the budget of each division.

We strongly encourage all of the divisions, however, to recognize the need for instrumentation funding. Their estimates for the fraction of their total budgets that will fund instrumentation range from about 4.5 percent for the Antarctic program to about 15 percent for the mathematical and physical sciences directorate. Within that directorate, for at least one division, the estimate is nearly 18 percent.

These estimates suggest a rather considerable increase from fiscal year 1982 to fiscal year 1983 in the budget we are presenting to you. Within the stringent budget constraints which we all face, NSF is making a strong effort to increase instrumentation facilities in the country's laboratories.

The CHAIRMAN. I would like to ask the same question with regard to the women and minorities program. One of the very positive components of that program, of course, was the national research opportunity grants for women and minorities who are just getting started in the scientific community or who are reentering the scientific community after a hiatus.

Has the Foundation planned to continue this aspect of the women and minorities program? If so, how do you monitor it among the separate directorates?

Dr. SLAUGHTER. The national research opportunities grants program, as you correctly say, was begun in fiscal year 1981. We examined the program to determine how we could keep it in place in fiscal year 1982 and fiscal year 1983. It appears that the program which makes the most sense is the visiting professorships for women program.

We monitor the program through the Office of Planning and Resources Management, and we expect in fiscal year 1982 to make eight such awards to women who are either in industry or who would like to join a university faculty and do research. That program in fiscal year 1983 will be increased to about 15 awards. We also hope to continue the planning consistent with a report we provided you on expanded programs for women scientists; we will be communicating with the committee staff.

The CHAIRMAN. What progress can you cite on the women's and minorities' programs? I would like to compliment NSF on its first report to the committee in accordance with the provisions of the 1981 NSF Authorization Act. I think it was well done, but unfortunately the statistics you accumulated serve only to underscore the problem, it seems to me.

Realizing that things are beginning to get off the ground, I wonder if you could give us some kind of an idea of the level of service this program has made thus far.

Dr. SLAUGHTER. Having looked at all aspects of that program, we are doubling the effort in visiting professorships for women for fiscal year 1983 to a level of $1 million. Two programs are in operation for minority groups. One is the minority research initiation program, which will be increased from $1.7 million in fiscal year 1982 to $2.5 million in fiscal year 1983; we expect to make approximately 25 awards.

In response to the President's initiative for historically black colleges, we have expanded NFS's program for research improvement in historically minority institutions. It will be increased from $.5 million in fiscal year 1982 to $2 million in fiscal year 1983 to provide, we hope, at least 10 awards.

We feel NFS is making progress in a constrained environment with these focused programs. That is not, however, the limit of the Foundation's activities in this effort. All NSF directorates recognize the importance of activities to improve the level of participation of women and minorities within their research disciplines. I have asked each of the assistant directors—and they in turn have asked each of their division managers and program managers—to develop programs and report on how NSF can put into place some mechanisms to address the committee's concerns.

The CHAIRMAN. The science education section of the women and minorities program also covered the handicapped. I know that Senator Kennedy will probably want to ask some questions in this area as well. I would like to ask you at this point the following question: What provisions have been made to include the physically handicapped in our NSF program, given the proposed elimination of everything but fellowships in the science and education directorate?

Dr. SLAUGHTER. I should have included the handicapped in my remarks about the extension of those programs to all directorates of the Foundation. The engineering directorate, in particular, has a major responsibility for addressing some of the programs for the physically handicapped. The directorate has put into place research programs for prosthetics and for specific research proposals designed to improve the tools available to the physically handicapped for use in science and technology. That activity will be continued in fiscal year 1983.

The CHAIRMAN. I am also interested in your thoughts regarding the effect the elimination of the science and education programs has had on the progress you are making in fairly distributing NSF awards to States and institutions. Many of the science and education awards were to institutions trying to upgrade the quality of science instruction with an eye to becoming more competitive for research grants.

Dr. SLAUGHTER. Several of those programs were oriented toward smaller institutions. NSF had a program in the science and engineering directorate which provided specific support to improving opportunities for 2-year and 4-year colleges. Again, that is a program we are determined to keep; it will be considered part of NSF's total effort. We will monitor the Foundation's performance in making awards to those institutions even though there will not be a focused program in fiscal year 1983.

The **Chairman**. How far along is NSF and the Science Board in formulating the new Science Education Commission? Are you free to tell us who has accepted positions or whether you have designated any positions thus far?

Dr. **Slaughter**. As Dr. Branscomb said, we had hoped to be able to announce the Commission today; one or two details make it impossible to do so. However, I expect we will be able soon to release the names of the members and describe the charter and activities of the Commission.

The Commission will have about 18 members who by background, reputation, and experience have all demonstrated a strong interest and abilities to assist NSF in addressing the problems of science education. As I said, Dr. Perry represents the quality of the persons who will serve on the Commission. We are proud to have received their acceptances to serve.

The **Chairman**. Even though I expect you would like to leave politics out of any discussion here, it should be obvious to you that science education is an issue which is bipartisan and concerns every one of us on this committee. What provisions are there for participation of Congress in the Commission's activity?

Dr. **Slaughter**. We hope we would have a strong tie to the Congress and certainly to this committee, which has played such a strong role in helping NSF to focus on these problems. We would identify avenues for communicating with you and the committee staff. Dr. Branscomb.

Dr. **Branscomb**. Let me observe that the Commission will report to the National Science Board, and I assure you that the Board will be responsive to your interests and those of other Members of Congress. However, the Board will take ultimate responsibility for translating the Commission's work into action.

The **Chairman**. Thank you. My 10 minutes are up.

Senator Kennedy.

Senator **Kennedy**. Thank you very much, Mr. Chairman.

I want to welcome the panel to the committee. Rather than taking the time of the committee, Mr. Chairman, I would like to insert my statement in its entirety in the record as read, perhaps following the statement of the chairman. I voice a number of the concerns which have been expressed by the Chair in areas involving women, involving minorities, and involving the handicapped.

The **Chairman**. Without objection, that will be done.

Senator **Kennedy**. Could you tell us what requests you made of OMB and what areas they reduced in your request? What was your budget recommendation to OMB?

Dr. **Slaughter**. As part of the budget planning, NSF constructed, as did every other Federal agency, a series of budgets representing certain initiatives. I am sorry that I do not have the precise figures of those budget levels with me today.

There were budget negotiations and changes from NSF's original request. However, those changes resulted largely from guidance of the Office of Management and Budget and the Office of Science and Technology Policy.

Senator **Kennedy**. I understand that. I understand the position that you are in. However, we also have some responsibility in this area. I want to try to find out who is making decisions with regard to the National Science Foundation, whether it is those who have the principal responsibilities who come up here before the Congress and whose positions in terms of the Congress—we make a judgment in terms of their competency and their interest. I think we have three outstanding individuals here. I am familiar with all of your extraordinary work to the NSF and to this country. I am a great believer in what you have done.

However, I also want to find out, as one who is very much concerned about where this country is going in terms of the areas of science and technology research, what your real recommendations are. I believe as a representative I am entitled to that.

OMB does not come up here. They do, but they do not come up here to the committee, but you do. I think we are entitled to find out where these principal areas are.

I am primarily concerned about science and engineering education, but I am most interested—and I have had other members of administrations under Democrats as well as Republicans who have indicated what request they made and what came out. I think we are all serious enough to understand how the process works.

I think we are entitled at least to find out where the principal areas are that you made the request and where the principal areas of reduction were. That is an important responsibility. We may make a different judgment on this.

I understand that you are prepared to defend this particular proposal. I understand that. I will come back to some of the specifics, but I would like to know in which areas primarily there were reductions where you had made requests.

Dr. **Branscomb**. I would be glad to describe the Board's guidelines to NSF in August 1981, after we had completed 6 months of work in developing priorities for the agency budget. I do not have these in dollar numbers.

Senator **Kennedy**. Fine.

Dr. **Branscomb**. The guidelines were issued as substantive priorities in five major areas. One was electrical, computer, and systems engineering and aspects of engineering important to productivity. In the mathematical and physical sciences, as Dr. Slaughter said, computer science is the most rapidly developing field. We need to respond through research in computer science.

Another in which the Board saw unusual opportunity for research was the Earth sciences, particularly research into the continental crust of North America; the Board gave that field a priority.

A third priority is the need for a stable base in social and behavioral science research. The critical data base collections are now becoming useful for multiple purposes; these bases must be sustained because they take a long time to develop.

In science and engineering education, the Board put priority on restoring the fellowship program to the scale of previous years, on subject matter training for significant numbers of secondary school teachers, and on a program for undergraduate faculty development.

In facilities, the Board was concerned about scientific ocean drilling and converting the *Glomar Explorer*, a university research laboratory modernization equipment program in which the Foundation might take a lead agency role, and funding for the 25 millimeter telescope. I might add it was obvious that NSF would not obtain approval for the telescope unless the fiscal year 1983 budget was set at a high level.

The Board, in summary, tried to maintain an aggressive posture in the critical areas of research opportunity and to maintain the fellowship program for students now in the universities, particularly engineers in graduate training because there is a shortage of engineering faculty.

The Board also wanted to address the issue which we discussed earlier: precollege education in mathematics, science, and technology. The Commission, I hope, will develop a broad consensus and a broad base of activity, not just by NSF, to address that problem at local, State, and Federal levels.

Senator KENNEDY. I asked a broad question and you gave me a broad answer to it.

Dr. BRANSCOMB. You can imagine increases were needed in those areas; in others, the Board trimmed back.

Senator KENNEDY. It appears to me that you did in a number of those areas which you indicated at the outset of your comment. You did well in terms of percentage increases. It just seems to me that the National Science Foundation ought to be the principal instrument, if there is an instrument, of Government that is articulating as effectively and as forcefully and as powerfully as possible the importance to this Nation of investing in research, in technology, and in the kinds of scientific undertakings which are going to be absolutely essential to continue this Nation as an important economic society over the period of the years in the future.

I was chairman of the Health Subcommittee. Year after year we find out what Japan has been doing, what the OEC has been doing in the areas of research and development. Every year they are just beating us hands down. I cannot believe with this kind of budget that you are proposing here that they are not going to beat us hands down again.

In the meantime, we will be taking a second and a third place in terms of the new industries that will be the primary industries for this Nation over the period of the future.

I think many of us are aware of the obvious budget constraints placed upon us. Some take strong exception. That is our prerogative. People can make their own judgments back home.

However, to those who have the principal challenge for this country and our Nation's future in this area and who look at what is happening in terms of other nations, and then to have a policy statement such as we have in this testimony, I would like to reemphasize several points.

"I would like to reemphasize several points first"—this is page 9, Dr. Slaughter—"I would like to reemphasize, first, there is no question that science education at the elementary, secondary levels is facing severe problems"—I mean, we have known that for years—

"including declining numbers of students participating in sciences, declining achievement, low salaries for mathematics and science teachers, inadequate numbers and preparation of science and mathematics teachers, archiac teaching equipment. Despite the recognition that that problem exists, there is disagreement as to what the solution should be." Well, if you cannot agree on what the solution should be, how in the devil are we going to know what the solutions are going to be?

"Moreover, delivery of precollege education is basically a responsibility of State and local governments." Now you try to tell that to the State and local governments of California or Massachusetts or any of these other States that have the capability or the capacity to try to put that forward. Whoever is making that statement ought to travel around this country and talk to the departments of education and talk to the high school teachers and the college teachers that I have talked to because they would just say, "Senator, the person who made that statement has not been out in the field."

"Delivery of precollege education is basically a responsibility of State and local governments," and "Under these conditions, the wisest course for the Foundation is to play a catalytic role and help identify critical needs"—I mean, I have heard that language around here for years. That means keeping hands off. That means, "We do not have any responsibility, effective responsibility."

"To find and provide information and to encourage State and local governments"—I would just be interested in what you have done in terms of State and local governments. I can remember the program that was developed by Senator Scranton in Pennsylvania, outstanding, to bring science and technology into local communities, to bring the best that they had in that State, to apply it to local communities to try and meet some of their very special needs, let alone our national problems. However, that kind of effort was just abolished and has been abolished in recent times.

"To encourage State and local governments, scientific and professional organizations, private industry, and other Federal agencies to make the appropriate contributions in resolving it," and "The purpose of the NSB Commission is to formulate strategies and an agenda for action"—I mean, if someone was to say that that is a program of action for the United States of America for the period of the 1980's and how we are going to be able to continue to compete either with Western Europe or Japan, we are in a lot more trouble than I ever thought we were.

We will have a chance to express our amendments and we will run them up and down on this but it does seem to me that the sense of urgency that is expressed in that kind of a statement before this committee, I find as an individual to be enormously troublesome. Quite frankly, I know what happens with administration officials and I have talked to all of you long enough to know some of your strong personal views on this but still, you happen to be here——

The CHAIRMAN. I am sure you would enjoy being somewhere else at this point. [Laughter.]

Senator KENNEDY. Oh, they do very well.

Dr. **Slaughter**. As a matter of fact, not many citizens of the United States have an opportunity to talk to Senators of the United States, so I will count it as a pleasure.

Senator, let me say I am pleased that you feel so strongly about this; I really am, because we also feel strongly about it. If the management of the Foundation were given the opportunity fully to construct a program across the breadth of NSF activities that we felt was right, and if there were no limitations placed on finances, other than reasonable limitations, NSF would plan other kinds of programs. However, NSF has been given a bum rap. Part comes from the Congress where the science and engineering education program has received much warranted attention but also has been given assignments that have made it difficult for NSF to construct a systematic and coherent attack on the problems you mentioned.

NSF consequently has had several programs that were never supported at levels necessary for a real contribution. NSF has found itself in a position where $80 million was distributed over 25 or 30 programs. All perhaps should have been supported at $20 million each, if NSF were to perform so that people at the State and local levels would say, "Hey, NSF really helped us on that."

Last year, NSF found itself in a difficult situation where, after much debate on science and engineering education, the Foundation received $6 million more than the $15 million requested for fellowships. That $6 million certainly did not help NSF to apply a great deal of resources or talents to some critical problems.

I could fall back and wring my hands, but I do not like to do that. I feel that NSF must put something into place. What the Board has charged me to put into place does provide NSF an opportunity to do some of the tasks that you have pointed out. I am going to try mightily, and the Foundation is going to try mightily, to be in a different position when we appear here in a year or two. We will be here to talk about those tasks.

Dr. **Branscomb**. The Foundation hit a peak of activity in precollege science education some years ago. After Sputnik, the American people seemed to support an aggressive Federal leadership in education with respect to science and technology. At the same time, the research enterprise was growing rapidly. There were years when even 15 percent real growth actually occurred in basic research.

Those were times when the population was motivated, partly because of the challenge of Sputnik, partly because of missile gap debates and concerns about national security, then as now. Those were times when U.S. industrial might was unchallenged, when the industrial plant was still surviving after World War II, and when the United States experienced low inflation. The country made a lot of progress.

But NSF hit a peak a few years ago, and ever since then NSF's science education program has been declining a bit. You, Senator, kept calling the decline to the Foundation's attention, and the Foundation kept being tortured on a spit: How does it manage that problem within a political conception of the Foundation's limited role? Can the science education program be moved to a level at which it will begin to address what goes on in the 17,000 school districts—not just the few that NSF helps. At the same time, can NSF continue to move science research forward with adequate vigor?

It is obvious that that is a terrible tradeoff. There has been negligible real growth since 1972, for 10 years the research level has remained approximately stagnant in effort, not in current dollars. It would have been very, very difficult for the Foundation to accommodate what was necessary to establish a clearcut Federal leadership role across the country and give every student an opportunity in science.

Now the country is just as concerned about military preparedness as it was then. It is more concerned about industrial competitiveness than it was then. It has a worse educational system with respect to these priorities we are talking about than it had then. And now it has what until recently was strong inflation, high interest rates, and a terrible squeeze on the discretionary part of the budget.

What is really at issue here is a policy decision that must be made by the electorate, by the people of this country. That is, What is the Foundation's role in precollege education? NSF can do a lot by providing technical assistance—special programs to help teachers in high schools get access to university activities. NSF had quite a number of activities; there is no question they were valuable.

However, it is not those programs, or their absence, that caused the State of Connecticut to graduate one mathematics teacher this year, or causes a high school to decide not to offer 4 years of mathematics, or allows a principal to hire a mathematics teacher who has had but one semester of mathematics. I do not know how we fix that problem. That is the State and local problem we are referring to, and I do not know how we get a handle on it.

I am hoping very, very much that the Commission will help us establish a consensus on the Foundation's role. That will require that the Commission also help to define others' roles and help to produce some enthusiasm for addressing them.

Let me note that in between precollege education—which some, including many of the administration, think is not NSF's role—and the research—which everybody, including this administration, thinks is important and is NSF's role—there is the problem engineering education. I personally think it is a problem for which an unambiguous, strong, and early effort is really important.

I say so because the Japanese are not beating us with research; they do not do much research. They are not beating us with development. By and large, they pick up what is done here and move fast with it. What they are good at is production, and U.S. engineering schools are not training experts at production.

Fortunately, the enthusiasm Americans have for computers is going to help a lot because of computer-assisted design and robots. This country is a little late getting started in some of those areas, but that is an area we will move in. There, too, we need a clear-cut consensus that the educational aspect of that problem, not just research and education, is an important role for NSF.

Senator Kennedy. I think that is very helpful. You see, I think we have—I mean, obviously all of us have been around here long enough to understand you have certain parameters in terms of what you are going to receive, in terms of the budget figures. However, what I would hope is that you would be able to tell us, in terms of our trying to meet our responsibilities to the American people, say we need to do X and Y and Z, either in terms of research, in terms of investment in support of engineering.

The Japanese now have doubled the number of engineering graduates in the last 10 years. We have held about level, having a terrible time just holding faculty in engineering schools.

We see the movement now of research and development in the military area that is again going to draw from the civilian area. I think what we need are some flow charts and flow lines of what the implications of this are going to be in terms of our economy, in terms of jobs, where we are going to be internationally over a period of time, and we cannot do that. We cannot do it. This committee cannot do it. The only ones that can do it are the National Science Foundation and the basic administration.

I think what we have to have as we make these judgments is what the tradeoffs are going to be, so at least when we go back and talk to our constituents. We can let them understand what are the alternatives. We can let the American people make the decision.

However, if we get the sense that we can meet the Nation's responsibilities within these kinds of parameters, and we are doing a little shifting here and a little there, and we come up with additional resources in terms of engineering education and some of the other kinds of things that we are doing, arguing around $25 or $30 or $50 million, I think we are really not meeting our responsibility to the country on this. This is one of the central frustrations, I think, that we have.

I think just generally with regard to agencies of Government that would be enormously valuable and helpful to us but I think it is terribly important for us to understand what these flow lines are going to mean in terms of this country. I think in the areas of science, research, these areas that you, Dr. Branscomb—obviously coming from one of the most successful companies in this country's history—and all of you have had a most distinguished career in each of your areas.

We have to know what you have been doing. You cannot tell me that IBM was not thinking 10, 15, 20 years down the line. You were, and that is part of the reason that they were so successful. I would like to just see the NSF try to give us some guidance about 10 or 15 years down the line. Let us make the choices. We have to wrestle that around in terms of the political process but at least give us the best judgment of the best minds about where we can put resources in order to try to deal with the country's future.

Dr. **Branscomb**. Senator Kennedy, your request is a reasonable one. I suspect the National Science Board has not done as well as it would like to have done in addressing those global issues. I would like to comment that it is not obvious that the best place to address them is in an authorization hearing, although it is not an irrelevant issue. However, I hope that you also will challenge us to give you that kind of information on other occasions, where we can get at the substance, without having it coupled tightly to 1 year's budget.

Senator **Kennedy**. That is right, and if I could I will just put the figures in the record, the OECD and NSF figures, what has happened since 1964 through 1978, the percent of science and engineering research and development. The United States is down 30 percent. Germany is up 51 percent; Japan, 25 percent.

I am sure we are aware of the different needs of the country. Japan does not have the military budget we do, and there are other factors. However, I do think, even given all of the various considerations, there is a flow line that is taking place in our society, and I think there is an agency that has to awaken this country as to what our needs are going to be. I do not think there is one that can do it like yours can, and so I will keep talking with you.

Thank you very much, Mr. Chairman.

The **Chairman**. Thank you, Senator Kennedy.

I want to compliment Senator Kennedy for the work that he has done with the National Science Foundation through the years. He has done a lot of work, and, of course has been one of the leaders of this area. He has taught me a lot since I have been on this committee. Therefore, I am grateful to be able to serve with him.

I am really concerned about the instrumentation, among other things, that our colleges and universities have and that it is woefully deficient to teach the sciences. Last week I was told by one of the top college presidents in the country, I believe from Senator Kennedy's State, that last year, if his recollection is correct, in the whole State of California, 23 million people, they graduated 1 Ph. D. in mathematics. If that is true, it is a pretty pathetic record and a good reason for wanting to turn science around in this country. I do not know, however, if it is true, and I certainly hope it is not.

Dr. **Branscomb**. Probably one mathematics teacher, I guess, lots of Ph. D.'s in mathematics, none of whom was interested in teaching in the high schools.

The **Chairman**. That may be, but we have to try to solve some of these problems.

I will submit some written questions as well. We are grateful for your——

Senator **Kennedy**. Could I, just on your issue of instrumentation, Dr. Branscomb, you gave what a company would have to pay in terms of taxes in order to be able to have it useful for them to make the contribution. What is your own sense of how realistic that is? What I would like to find out from the NSF is what works. Is it taxes, or do we have to foot the direct appropriation in order to get the instrumentation out? I am prepared to go either one, quite frankly, but I would like to know—what I am not interested in doing is putting a tax proposal in that is not going to be effective and may be abused, nor should we use the direct appropriation if it is not going to be effective. I remember your testifying. What is your own estimate, coming from that industry?

Dr. **Branscomb**. The tax incentive for donations is a useful device. As I suggested in my testimony, the Treasury regulations have yet to describe the details. Therefore, there may not be action quickly under the new law. I do not believe it is a substitute; I do not believe it can have any meaningful impact on the $2 billion shortfall discussed by Dr. Langenberg.

However, it is important to remind the companies that the Government is encouraging their contribution of this kind. And the companies will benefit by discovering that researchers in universities are imaginative and demanding customers; the companies will get valuable feedback from the use of their equipment. The real problem, in my view, is to get the research community to appreciate that it also must take a long-term view. The research community may have to abandon the view that next year's budget will be better than this year's. The research community may have to cut back the number of people engaged in a project in order to get the equipment. We in the NSF simply find ways to insure that NSF grant applicants do not underestimate the importance of doing their work with the most modern equipment.

Senator **KENNEDY**. Is the percentage on it from the tax point of view about where you would come out?

Dr. **BRANSCOMB**. Yes, the feature of section 222 that allows a deduction of up to half the difference between the sales price and the manufacturing cost is very good. That gives a generous incentive to a company that uses low markups anyway, and there are certain circumstances in which it can cost almost nothing to donate equipment.

The **CHAIRMAN**. Well, I hope you can encourage a greater number of companies around this country to participate more fully in such programs because, everywhere I go, universities are telling me their equipment is woefully inadequate. That is true across the board, even in the case of vocational education. They cannot get the equipment to teach some of the basic skills.

Dr. **BRANSCOMB**. The Board is discussing another area, trying to find out how to do a piece of useful work. We really need a better system for planning major capital facilities for science. We tend to do those on an annual budget basis, but there is always the problem of starting a project—I am talking about an oceanographic ship or a telescope or other large facility. The Government does not have a good way of making a 5-year plan for such facilities and of committing the funds to start those projects on a timely basis. Too often, we spend several budget years in pushing a new project gradually up the priority ladder. Finally it gets started, and then the construction is strung out, and the project ends up costing more.

The real problem is that a project's value depends on its timeliness. If the ideas in it are obsolete by the time it is finally done, then we do not get the value we should.

I also suspect we could do better by planning some of those facilities collaboratively with friendly countries. We do a lot of such sharing now, but the capital facilities issue is going to be increasingly important as budgets are kept tight for a long time.

The **CHAIRMAN**. Thank you. We will both submit questions. We appreciate your coming, and thank you for your testimony.

Our next witness will be Dr. F. James Rutherford, chief education officer, office of science and technology education, American Association for the Advancement of Science. He will be accompanied by Mrs. Sarah Klein, who is president of the National Science Teachers Association and general science teacher at the Roton Middle School in Norwich, Conn.; Dr. Lewis S. Salter, on behalf of the Independent Colleges Association and president of Wabash College in Crawfordsville, Ind.; Dr. John E. Gibson, on behalf of the Council of Graduate Schools in the United States, and commonwealth professor and dean of the school of applied science and engineering at the University of Virginia in Charlottesville; and Dr. Anne M. Briscoe, on behalf of the Association of Women in Science, and director of the biochemistry laboratory, Harlem Hospital Center at Columbia University in New York City.

We are very happy to have all of you with us today. Welcome to the committee. Dr. Rutherford, we will take your testimony at this time.

STATEMENT OF DR. F. JAMES RUTHERFORD, CHIEF EDUCATION OFFICER, OFFICE OF SCIENCE AND TECHNOLOGY EDUCATION, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, ACCOMPANIED BY SARAH KLEIN, PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION; DR. LEWIS S. SALTER, ON BEHALF OF THE INDEPENDENT COLLEGES ASSOCIATION; DR. JOHN E. GIBSON, ON BEHALF OF THE COUNCIL OF GRADUATE SCHOOLS IN THE UNITED STATES; AND DR. ANNE M. BRISCOE, ON BEHALF OF THE ASSOCIATION OF WOMEN IN SCIENCE

Dr. **Rutherford**. Thank you, Mr. Chairman. I want to thank you for having me here, and particularly to be in the company of such a distinguished panel.

It is a time when one could be very discouraged about giving testimony on what is clearly one of the most urgent and in many ways neglected problems in our Nation, the quality of scientific, mathematical education, yet I am not altogether pessimistic. I think that this committee under your leadership and previous leaderships has in fact had a deep and abiding interest in educational problems of the Nation, are aware of the issues now, and are ready to move to bring about some national action. At least, I hope that is the case.

While I speak for myself and for the American Association for the Advancement of Science, in preparation for this testimony, Mr. Chairman, I did talk with most of the associations related to education and to science. I have talked by telephone and in a few visits to some school board members, school administrators, science and mathematics teachers in the country, some engineering faculty members, some people in industry.

There is no question, Dr. Slaughter is right. The problems are known. There is no mystery about what is wrong with the deterioration of education in this country. All of these people, whatever their situation is, know the same kinds of things.

Where I would differ, and where the people I have talked with differ from the testimony given by the National Science Foundation, is that in fact we do know solutions, perhaps not to all of the problems. There are some that are very incalcitrant but on many of the issues we know what to do.

What we do not seem to be able to do is to get a plan, to get a conception, to organize ourselves and decide how the cost is going to be divided as between the various levels of Government and between Government and the private sector. It is more of a question of will and conception and determination than of lack of knowledge.

Therefore, in my testimony which I will submit for the record and not read——

The CHAIRMAN. Without objection, we will put it in the record at the appropriate point.

Dr. RUTHERFORD [continuing]. I would like to take just a few minutes to suggest what a few of the problems are and what in fact can be done about them.

The school population in this country is decreasing, and will continue to do so on the whole, although there are some fluctuations, for the next two decades. The pool of people from which we will draw our scientists and engineers of the years of the nineties and the first years of the new century, that population is decreasing.

If we intend to keep up a flow of scientists, engineers, and technicians into the future, we have to draw a larger and larger fraction of those students into scientific careers. Instead, of course, we are getting a smaller fraction of the people who traditionally went into science and engineering, which is to say white, middle-class males, and we have just begun to make progress in learning how to draw women and minorities and people from poor families into scientific careers. If we fail to do that, quite apart from questions of equity, we will not be able to sustain the scientific effort.

An investment in science education, Senator, is not primarily an investment in education; it is an investment in scientific research. It is just that the investment is being made 15 and 20 years early.

What to do about that problem? Well, we have a resource center experiment in which the Government invested a considerable amount of money and is now getting results. We have had a series of programs to help bring women into scientific careers, as we have testimony today from Dr. Branscomb, and those are beginning to work.

We have learned how to go down to the small children in the grade schools and get them to come Saturday after Saturday for science, mathematics, and engineering activities, so we do know how to begin to reach the minorities and women but in fact we are stopping almost all of those programs, and I do not consider it for a minute to be a substitute to say that each of the other research programs in the National Science Foundation will do something about it. They do not know what to do about it. Their skill comes in finding the best researchers in the country and supporting them.

Now when we look at the elementary schools in this country we see that the best science instruction we ever had was when provisions were made to provide science specialists to help the elementary teachers. The typical teacher in this country who teaches the elementary grades does not have a science or mathematics background. A scheme was developed with National Science Foundation funding to provide specialists who would help the teachers, go from classroom to classroom.

That has almost disappeared, and as a consequence in our classrooms today our elementary students get a few minutes per week of science. It amounts to reading a book and talking about it, and yet we know how to provide specialists to do something better than that.

When we look at the high school situation, the junior highs, and high schools, of course the disaster is most apparent there. Teachers are leaving. A large fraction of them were never trained in the field. The ones who are there and were once well-trained have been 5, 10, 12, 15 years without any updating in their subject matter fields.

Again, programs to help teachers go way back to the early 1960's. Ask the teachers, ask the principals, ask the parents if they worked, and the answer is unanimously yes. Those programs were successful.

Furthermore, contrary to what we heard this morning, it really is not a question of grassroots support. Congressmen who have taken the trouble to go to the schools and colleges in their districts will tell you that the parents unanimously support the notion that teachers get this kind of upgrading, and they do not consider it an infringement on their rights and privileges.

The CHAIRMAN. Dr. Rutherford, could I interrupt you for a second?

Dr. RUTHERFORD. Yes.

The CHAIRMAN. I will have to step out and take a phone call and then I will be right back.

[Recess taken.]

The CHAIRMAN. Go ahead, Dr. Rutherford. Sorry for the interruption.

Dr. RUTHERFORD. Thank you, Senator.

Just to conclude about the precollege education, I was saying that we do know how to provide opportunities for teachers to be trained in their field and we also know how to serve teachers in another way. Teachers around the country had always counted on their very best students, the two or three each year with real talent, having the opportunities to go to the colleges and universities during the summer for special programs. It is a way of keeping the talent alive that the teachers themselves could not provide.

That program, involving literally thousands of bright young people every year, now is in jeopardy, and I cannot believe that a nation is prepared when it knows how to do this to go 1, 2, 3, 4 years of young people who will be left out, lost to the Nation because of that failure to do what we know how to do.

When one looks at the undergraduate level, as Dr. Salter could testify in much more detail than I, we see a different sort of problem there. During the sixties the undergraduate education in America probably became the best in the world, and one of the reasons was because the NSF helped develop new programs in science and mathematics, engineering, at the undergraduate level.

Institutions themselves are up against it. That kind of forward investment money is difficult for them to come by, let alone the instructional apparatus that is needed to teach first-rate science at the undergraduate level. What we have had are programs, a variety of programs for upgrading the quality of undergraduate science teachers, for providing teaching apparatus, and for helping alert colleges to revitalize their programs so that they could begin reaching not only the science and mathematics students but those undergraduates who are going to become our businessmen, our legislators, our school superintendants, and who in this day and age themselves need to understand science and technology.

Finally, when you look at the graduate education, there has been a great deal of talk about that, mostly in the context of computer science and engineering but I think there is a longer term problem. The problem is one that has roots and stems going clear back to the precollege years but nevertheless it is a problem that we cannot allow to just drift along. It is kind of an irony, an unpleasant one, that in this Nation—still, perhaps, the world's leading technological nation—that we can somehow or other have to depend upon foreign professors to teach a large fraction of the engineering in this country; that we have to import graduate students in engineering and computer sciences.

Therefore, the problem is severe there and we have over the years learned how to help the engineering schools with some very productive programs. There is no reason, in my judgment, why we should curtail them.

Finally, all kinds of learning does not take place in schools and colleges, universities, and graduate schools, but a great deal of it goes on outside. It happens in science museums that young people get interested in science. It happens because they watch television and see "Three, Two, One, Contact," or some other program that gets them interested in science and technology and thinking about themselves and their futures in those fields.

Once again, producing these kinds of things, making these opportunities available, is not the kind of thing that can be done helter-skelter without leadership from the National Science Foundation.

In brief, we have some problems; they are severe; the Nation's future depends upon solving them. Some of those problems we know how to deal with, and we can go to work and do it even while we study something more aggressive and ambitious. I have nothing against a commission, and I have assured Dr. Slaughter and Dr. Branscomb that the scientific societies and the education associations of this country will support that commission in every way possible as long as they are doing a quality job.

On the other hand, it does not seem to make sense given the severity of our problems, simply to stop while we do a study and then tune up again 2 or 3 years from now. Whatever the administration's view may be, I urge that Congress make its own judgment on this issue and come to the conclusion that even while we restudy and reorganize ourselves, we go ahead with some of the most urgent programs that will serve our young people, upgrade our teachers, help our colleges and universities get on with this job.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Rutherford follows:]

TESTIMONY

TO

COMMITTEE ON LABOR AND HUMAN RESOURCES

OF

THE UNITED STATES SENATE

IN REGARD TO

1983 AUTHORIZATION
FOR
THE SCIENCE EDUCATION COMPONENT
OF
THE NATIONAL SCIENCE FOUNDATION

PRESENTED BY

F. JAMES RUTHERFORD
CHIEF EDUCATION OFFICER

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
1776 MASSACHUSETTS AVENUE, N.W.
WASHINGTON, D.C. 20036

DATE: APRIL 15, 1982

TESTIMONY
TO SENATE COMMITTEE ON LABOR AND HUMAN RESOURCES
IN REGARD TO
1983 AUTHORIZATION FOR THE SCIENCE EDUCATION COMPONENT OF THE NATIONAL SCIENCE FOUNDATION

Thank you for permitting me to testify before you on what I regard as one of the most urgent matters facing the American people today, namely, the quality of science, mathematics, and engineering education throughout our country.

While I speak for myself and the American Association for the Advancement of Science, in the preparation of these remarks I consulted widely with other scientific societies, science and mathematics teaching associations, higher education associations, representatives of school boards, school administrators, science and mathematics teachers, college and university scientists, and scientists and executives from business and industry.

As I spoke to these individuals a unanimity of opinion emerged: science and mathematics education is in rapid decline in the United States. Furthermore there is widespread belief that the price of this decline to the Nation is prohibitive, since nothing less than a dangerous undermining of our economic health, productivity, and national security is the inevitable consequence.

Our industrial competitors, both friendly and hostile, have committed themselves to the advancement and aggressive use of modern technology to insure their position in the world. Not only fully industrialized nations, such as the Soviet Union, Japan, Germany, and France, but also many developing countries, such as the People's Republic of China and Brazil, are investing heavily in science education for all of their students. They know that it takes not only a steady flow of scientists and engineers, but also technologically literate workers and leaders across the full spectrum of occupations to flourish as a strong and technically sophisticated nation.

Everywhere I have turned, not only in Washington, but in many states across the country, I have found our science educational system deteriorating, especially at the pre-college level. The complexities of relationships within the system make the reversal of this trend terribly difficult. On the one hand, the need for strong science, mathematics, and technological education is national. Yet, on the other hand, action must be taken in tens of thousands of separate school districts, at thousands of individual colleges and universities, in fifty different states, and by a complex private sector made up of legions of independent companies and organizations. Clearly, the solution to this national crisis is to form and energize a national partnership--a cohesive, coherent, and determined effort at all levels and in all sectors. Individual schools, colleges and corporations, and each and every state will play an essential role, but the role of the federal government is unique and absolutely necessary.

The deterioration of our science education system is evidenced by falling test scores, a retreat from the study of science and mathematics at all levels by students, and the increasing difficulty business executives have in finding enough technically skilled workers. When we look at the system, this is what we see:

- As the school population decreases in the next two decades, it will become increasingly difficult to maintain an adequate supply of highly qualified scientists and engineers. To address this shortfall we need to increase our efforts to recruit professionals from an extended pool of American citizens capable of becoming scientists and engineers, a pool, that is, that includes a much greater number of women and minorities. Not only is this a matter of equity, but it is also necessary to our common good. We know how to accomplish this. For example, a variety of programs such as the Resource Center for Science and Engineering Education, minority graduate fellowships, summer laboratory experiences for high school minority students, and Saturday Academies for young children have, with very limited funds, begun to show impressive results. Also, various programs for attracting women in science have been very effective. For example, the NSF-sponsored "Women Moving Up" project at the University of California at Berkeley has been responsible itself for the re-entry of many women in the scientific professions. These are examples of programs that states and local communities have not been able to support by themselves and would not be able to initiate at this time.

- At the elementary school level, instruction in science has almost ceased, being no more in most classrooms than a few minutes a week of reading from textbooks. This deplorable condition came about when the federal government withdrew from the states funds for science specialists to help teachers conduct interesting science activities for children.
- In secondary schools we are seeing a dramatic and disturbing decrease in the quality of science and mathematics teachers. For understandable reasons having to do with income and working conditions, many of the best chemistry, physics, and mathematics teachers are leaving teaching for jobs in industry. Their positions in the classroom are not being filled by other qualified teachers but more often than not by teachers

who have little or no training in science and mathematics. Undergraduates are not choosing to prepare for careers in science and mathematics teaching; the schools are not hiring new science and mathematics teachers; and the system is simply winding down. The data assembled from recent surveys carried out by the National Science Teachers Association (collected and presented to you in a written testimony) is dismaying: it shows that teachers who remain in the secondary schools are badly out of date in their subject matter. The NSF has ceased to provide training opportunities for teachers, while at the same time almost every other major country in the world has copied the NSF summer institute approach. The states cannot afford to provide opportunities previously supported by NSF; school districts have less income than ever before; and the local business and industrial communities do not have a surplus to invest in teacher training and in-service programs. Teaching salaries have so badly deteriorated in this country that teachers themselves cannot afford to go to the universities during the summer, and universities cannot afford to offer free instruction.

- Our undergraduate institutions not only initially prepare scientists and engineers but they also educate national leaders, politicians, business people, lawyers, and journalists--in short, the people who make the day-to-day decisions that determine where we will go as a nation. Clearly, these people need to be adequately prepared to operate effectively in a world dominated by science and technology, and yet the task of developing new courses, of outfitting laboratories, and of producing current learning materials appropriate to these students is beyond the resources of the individual colleges and universities.

In the past quarter of a century, the strength of our colleges and universities in the technical fields was in great measure due to the investment of the National Science Foundation in improving undergraduate and graduate science education. With that support gone, the undergraduate institutions can only become weaker and surely will not be able to provide the quality of education demanded for the nation's welfare.

- In graduate education the problem is especially severe with regard to engineering and computer science. This is because, as Allan Bromley, Board Chairman of AAAS, has so forcefully pointed out, as a nation we are eating our scientific and technical seedcorn. Because of the draw of the market, B.S. engineer graduates are going directly into business and industry rather than entering doctoral programs. Our supply of researchers in these fields and of professors who can teach the next generation of engineers and computer scientists is rapidly depleting. Institutions have responded in two ways. Engineering schools and computer science departments are restricting admission even though there is a national shortage. They are also depending more and more on foreign instructors and foreign graduate students in their advanced programs. It is ironic that America, which thinks of itself as the world's leading technological power, must import engineering instructors in our schools. It is even more ironic that the nation is spending its dwindling resources to support foreign graduate students in scientific and engineering fields. While nations such as Iran, Japan, and Saudi Arabia use their countries' resources to educate their students at the pre-college level, the U.S.

neglects the science education of its students and even provides a federal subsidy for the graduate education of these foreign students. In the final analysis Congress has a major responsibility for facing up to this national problem.

- Even if we had better-prepared teachers in our schools and colleges, we would still be in trouble, for the support system that has enabled teachers to keep pace with the state-of-the-art is disappearing. The schools and colleges have archaic equipment that is in disrepair and they cannot afford to replace it. More and more, instruction in science is "textbookish" and badly out of date, for the schools cannot pay for the supplemental materials that can enliven and update instruction. The withdrawal of federal support for our schools, colleges, and public libraries means that these essential elements of the educational enterprise, so vital to good teaching, will be weakened. It should also be noted that the withdrawal of federal support from science museums and from the production of science television programs such as "3-2-1 Contact" means that still another dimension of the science education system is being undermined.

The major thrust of my remarks has been to emphasize that we have already identified the problems in science and engineering education and do not need to spend another two to three years trying to figure out what is wrong. As a nation we need to get on with the job right now of strengthening our science education enterprise. We have tried and true mechanisms for dealing with some of the problems, and there are abundant new ideas available for addressing the others. What seems to be in short supply is the will to implement them.

I energetically urge you to insist that the National Science Foundation continue to support essential programs in science and engineering education even while the new commission is conducting its study. We must not lose momentum, for the Nation cannot afford it.

The **Chairman**. Thank you. I want to thank all of you for appearing here today, and particularly you, Dr. Rutherford, for your excellent testimony.

If I pose a question to any particular member of the panel, any of you may comment, so please feel free to do so.

It seems as though we have a "Catch-22" situation here: Elementary and secondary students are not getting quality instruction due to the decline in both number and quality of teachers, and the number and quality of teachers is falling off due to a decline in the number of undergraduate students who choose teaching science as a career.

Where should NSF target its funding—on students or on teachers?—and what would be the ramifications of either choice? Perhaps each of you would care to comment on this.

Dr. **Rutherford**. I think Mrs. Klein from the National Science Teachers Association might be a good place to begin.

Mrs. **Klein**. Would you repeat that last part?

The **Chairman**. Where should NSF target its funding, on helping students or teachers or both? What would be the ramifications of either choice, if you have to make a choice in order to solve this problem?

Mrs. **Klein**. We can hardly target on students if we do not target on teachers first. I believe that the confidence of the science teachers has been shattered, for whatever reason, many reasons that have nothing really to do with this point in time. However, I do know that with the support of the National Science Foundation, teachers have felt very comfortable with the upgrading of their backgrounds and with having additional resource teachers, as Dr. Rutherford has pointed out, at the elementary levels. At this point I really think we have to think about these teachers before we can think of students.

Students are, I believe, a direct result and the learning that goes on is a direct result of the teachers, their preparedness, their confidence to work with these students. Too many times the teacher has become a social agency more than an academic agency, and the teachers have so many other additional responsibilities in addition to just teaching students. I think, with that in mind, that teachers should be the target. They will directly influence the students.

The **Chairman**. Both Dr. Rutherford and yourself, Mrs. Klein: Are there any other reasons, besides expected salary, that undergraduate students bypass teaching careers?

Mrs. **Klein**. Yes. I think one of the ways is through the science centers. I think they have been a big help but many of those have been discontinued. This is another way in which the NSF has helped, through establishing these science resource centers. In our testimony from the National Science Teachers Association, we have recommended that there be some science centers established with part of the funding that is available. Therefore, I feel that this is one way that we could very definitely help restore this confidence.

The **Chairman**. Very good. Let me ask you this question, Dr. Rutherford: Do you see any reasons besides salary why more graduate students are not going into——

Dr. **Rutherford**. Yes. I think there are a whole set of reasons, Senator, and I would say that the problem of the teachers now in the school is a very different problem than the ones who are not going in, two separate problems. The people who are already there, I think we know things to do to help them.

The problem of why people are not going into teaching careers in science and mathematics is much more complex. It is salary to some degree but to I think a larger degree it is the working circumstances. A teacher today has no budget; a teacher today has five large classes. They feel looked down upon. They feel as a profession, if they go into it they will not have status in their own community any longer. They knew that when they get there they cannot do things you like to do in science, which is laboratory work and things with your hands.

Therefore, I think there is a perception that it is really not a very nice job these days, let alone the fact that you are not being paid very well.

The CHAIRMAN. I see.

Dr. Salter, on the assumption that the undergraduate education is the spoke of the science education wheel, that is the place where teachers are trained for both the precollege and college levels. What do you think is the greatest need for undergraduate science education?

Dr. SALTER. I think that the missing link in terms of the appallingly low number of young men and women who see the teaching of science as exciting, is the fact that the quality of science teaching that they have had both at the secondary level and now at the undergraduate level simply is not high enough quality to convey that sense of excitement. I think we want teachers who are excited about science and want to go into it. Sure, they want reasonable salaries but like you, I do not believe that it is economic factors that are solely the thing.

The CHAIRMAN. Could you give us some idea about the proportion of undergraduate students who take up math and science careers? Where do these new BA or BS graduates go?

Dr. SALTER. Well, at the moment, if they are in mathematics, physics, or chemistry they go right into teaching positions. We have had no difficulty whatsoever in placing the relatively small number of young men—we happen to be a men's college—who go into, want to go into secondary teaching. They have several job opportunities but that is particularly the case in the science area. There is a critical shortage, and I guess I suffered some sense of shock sitting here earlier this morning and listening to the Chairman of the National Science Board admit that he was familiar with the devastating situation with regard to secondary mathematics instruction, and yet to be a party to a systematic policy over the last few years which has systematically phased out NSF's involvement in science education.

The CHAIRMAN. Yes, Mrs. Klein?

Mrs. KLEIN. I just would like to make a comment at this point. One gets into the classroom, and as an eighth grade general science teacher I have five classes a day and each 40 minutes is another opening, another show. I would like to just reiterate this excitement that is expected. We at times feel as though we are in competition with the media for a "3-2-1 Contact" kind of production that goes on in the classroom.

Too many times science is thought of as literally "another opening, another show" for each group that comes in. It is exciting, yes, but not the kind of excitement that I think the general public would like to think of it as being. It is learning for learning's sake that is exciting and must be conveyed, and I think perhaps part of our responsibility is to change that image through some of the recommendations that Dr. Rutherford has suggested.

[The prepared statement of Mrs. Klein follows:]

TESTIMONY

TO

COMMITTEE ON LABOR AND HUMAN RESOURCES

OF

THE UNITED STATES SENATE

IN REGARD TO

1983 AUTHORIZATION
FOR
THE SCIENCE EDUCATION COMPONENT
OF
THE NATIONAL SCIENCE FOUNDATION

PRESENTED BY

SARAH E. KLEIN
PRESIDENT
NATIONAL SCIENCE TEACHERS ASSOCIATION
1742 CONNECTICUT AVENUE, NW
WASHINGTON, DC 20009

DATE: APRIL 15, 1982

The following testimony is presented by Sarah E. Klein, President of the National Science Teachers Association (NSTA). The NSTA is the largest science education organization in the world. It is the only science education organization that is concerned with the professional aspects of science education at all levels for all science disciplines.

Mrs. Klein is an 8th grade general science teacher at Roton Middle School, Norwalk, Connecticut. She is currently on leave to carry out her responsibilities as President of NSTA. Mrs. Klein has been active in NSTA for many years, and over the past year has visited schools, talked to teachers, and participated in numerous science meetings throughout the United States, Canada, England, and France. Mrs. Klein wishes to acknowledge the efforts of Bill Aldridge, Executive Director of NSTA, and of James Shymansky, of the University of Iowa, for documentation and preparation of this testimony.

The Crisis in Secondary School Science and Mathematics Education

Our nation faces unprecedented problems in science and engineering education. Most severe of these problems are at the secondary school level where there is a critical shortage of qualified science and math teachers. The paucity of supplies, resources, appropriate materials, and support have reduced the quality of science and mathematics education at the secondary school level to a point that U.S. national security and the nation's efforts toward improved productivity are dangerously threatened.

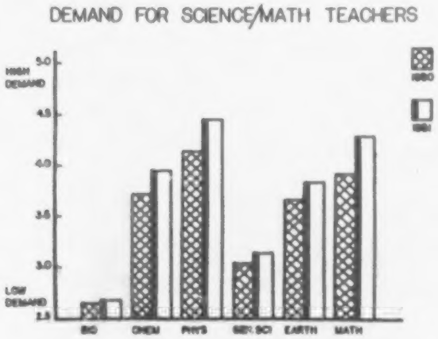
Shortages of Secondary School Science and Math Teachers

In the fall of 1980 and again in the fall of 1981, Howe and Gerlovich (1) surveyed the 50 state science supervisors to assess supply and demand for secondary school science and math teachers. Shortages were found for 1980-1981, and those shortages have become more severe in 1981-1982. As shown in Table I, this problem is national in scope, and the shortages are critical in physics, mathematics, and chemistry.

	Critical Shortage		Shortage	
SUBJECT	1980-1981	1981-1982	1980-1981	1981-1982
PHYSICS	21	27	22	15
MATH	16	18	19	25
CHEMISTRY	10	9	25	29

TABLE I

When the science and math teacher shortage problem is expressed in terms of demand, as indicated on a scale from 0 to 5, the results, shown in Figure 1, lead to the conclusion that the shortage has been critical and has worsened in the last year.

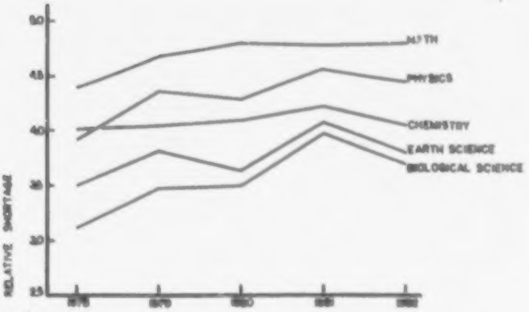


Based on a survey of state certification departments. From Trevor G. Howe and Jack A. Gerlovich, "National Study of Estimated Supply and Demand of Secondary Science and Mathematics Teachers," Iowa State University, 1982.

Figure 1

In surveys of placement officers conducted by James Akin (2) from 1976 to 1980, "considerable shortages" of teachers were found for math, physics, chemistry, and general science.

DEMAND FOR SCIENCE/MATH TEACHERS



Based on a survey of teacher placement officers. From James N. Akin, ASCUS Report, "Teacher Supply/Demand," 1981.

Figure 2

Severe Decline in Numbers of Persons Prepared to Teach Science and Math

In December, 1981, the NSTA surveyed 600 colleges and universities that have teacher training programs (3). Year-by-year data were acquired for the ten-year period of 1971-1980. The results shown in Table II and Figures 3 and 4 are shocking. There has been a 77% decline in the number of math teachers and a 65% decline in the number of science teachers prepared to teach in secondary schools. As shown in Table II, not only has the supply of persons trained to teach science and math severely declined, but the fraction of those trained who do go into teaching has also declined.

The combined effect is a 68% reduction in newly-employed science teachers and an 80% reduction in newly-employed math teachers since 1971.

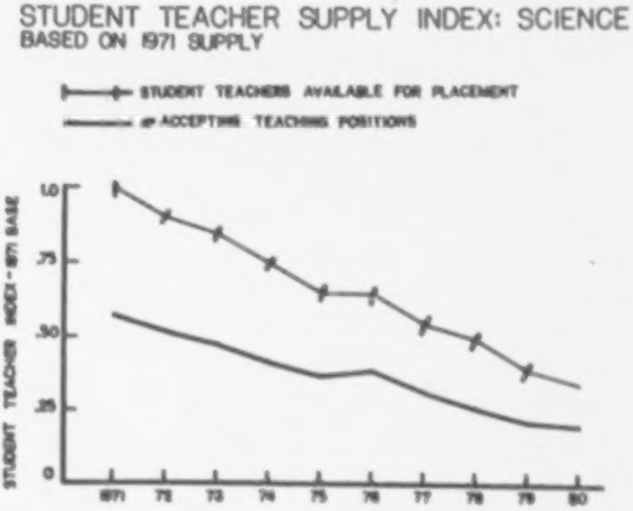
SCIENCE/MATH TEACHER SUPPLY DATA 1971-1980*

		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
SCIENCE	Graduating Teachers	100	90	85	75	65	65	55	50	40	35
	% Entering Teaching	59	58	58	55	56	59	56	52	54	54
MATH	Graduating Teachers	100	91	86	73	60	45	36	27	27	23
	% Entering Teaching	63	68	64	65	62	61	63	59	~~60~~	55

* Values represent percentages indexed to 1971.

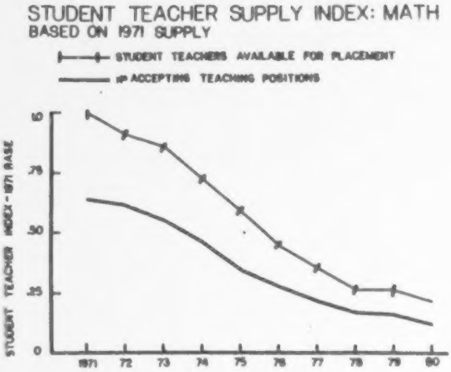
** Based on data from a nationwide sample of 140 university/college placement officers.

Table II



Based on NSTA survey of college and university placement officers. Conducted by J. A. Shymansky, The University of Iowa, 1982.

Figure 3



Based on NSTA survey of college and university placement officers. Conducted by J. A. Shymansky, The University of Iowa, 1982.

Figure 4

Employment of Unqualified Science and Math Teachers

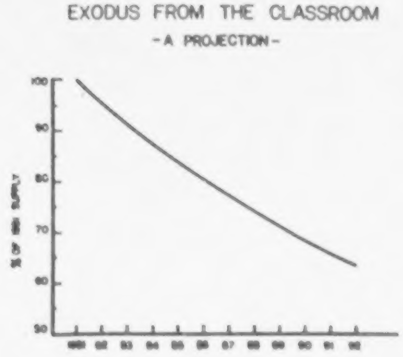
In another NSTA survey (4), also conducted in December, 1981, and analyzed by James Shymansky of the University of Iowa, secondary school principals provided the information. Among newly-employed science and math teachers, 50.2% were unqualified to teach science or math. They were employed on an "emergency basis" because no qualified teachers could be found. When these data are examined by census region, the results are especially bad in states where high technology industries require the best-trained science and math personnel. Table III shows, by census region, the percentages of newly-employed science and math teachers for the school year 1981-1982 who are unqualified to teach these subjects.

Census Region	Percentage of Newly-Employed, But Unqualified Science and Math Teachers	
	1980-1981	1981-1982
Pacific States	75%	84%
Mountain States	44	43
West North Central States	26	43
West South Central States	63	63
East North Central States	23	32
East South Central States	43	40
Northeastern States	11	9
Middle Atlantic States	40	46
South Atlantic States	48	50
NATIONWIDE	45%	50%

Table III

Ages, Experience, and Plans of Science and Math Teachers

The evidence of a severe shortage of science and math teachers at the secondary school level is overwhelming. To compound this problem, results of an NSTA survey of science teachers show that schools have an aging faculty and that one in four of the younger faculty plan to leave teaching completely. The average age is 41, and the average experience is 16 years. Almost 5 times more science and math teachers left teaching last year for employment in non-teaching jobs than left due to retirement. If the present exodus of qualified science and math teachers from secondary schools continues, the nation will have a net loss of 35% by 1992.



Based on the 6% rate at which science and math teachers left classroom teaching in the years 1980 and 1981

Figure 5

School Populations - Increasing or Decreasing?

Analyses of population data and of school projections compiled by the National Center for Educational Statistics suggest that science and math teacher demand will increase over the next several years.

Elementary school enrollments bottomed out in 1981 and are now on the rise. Secondary school enrollments will by 1996 have dropped only by 24% from their high in 1977. Then they will increase again for several years. The declines in qualified science and math teachers has already exceeded these enrollment declines by a factor of three.

Conclusions about Teacher Shortages

Independent recent surveys all show a severe shortage of secondary school science and math teachers. There has been a catastrophic decline in the number of persons prepared to teach science and math, and of those prepared, many do not take teaching positions. Secondary schools are employing record numbers of unqualified persons for science and math teaching positions because qualified teachers cannot be found. The problems are most severe in regions of the country where the greatest efforts will be made for defense preparedness and high technology industry. Thus there is a dangerous mismatch between scientific and technological training capability and national need.

Quality of Science and Mathematics Education

The severe shortages of secondary school science and math teachers and the resulting employment of unqualified teachers on an emergency basis is a major factor in the decline of quality in secondary school science and math education. For the teachers who remain in the science and math classroom, there are other constraints which have made the situation deteriorate further.

From the recent NSTA survey, we know that 60% of science teachers report recent cuts in their budgets for supplies and equipment. These cuts occur at a time when school labs are already obsolete, and when computers and other components of modern electronics are essential in an up-to-date curriculum. From the same survey, we learned that 79% of these teachers had not completed at least a 10-hour course or workshop in over ten years. Also, 69% have never attended a computer course or workshop. Finally, 40% have not attended a course or workshop since they began teaching, which has been an average of 16 years.

In another recent national survey conducted by NSTA, elementary school teachers provided the responses (5). Approximately 51% report that their undergraduate training did not prepare them to teach science. Furthermore, 71% of the school districts had no inservice training for science, and 64% no longer had science consultants assigned to their schools.

There has been much public discussion of declines in SAT scores, but less attention has been given to declining scores in the national assessment. There has been a decline in recent years, and now those declines are affecting even our best science and math students.

Prior NSF Support of Science and Engineering Education

There is, among those in the Administration, and among many others, the mistaken belief that science education has received substantial support, especially in recent years, and that since we now see all of these serious problems, the infusion of massive federal support has been a failure. The facts are quite the opposite. The NSF support for science and engineering education has been declining steadily and steeply for the past 22 years. Figure 6 shows how science education's share of the total NSF budget has dropped from a high of 47% in 1959 to its present low of 2%.

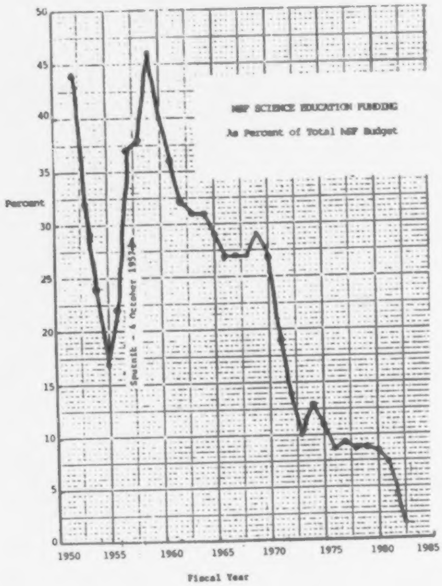


Figure 6

Support for pre-college science education has dropped even more sharply, from 72% of the science education budget in 1959 to 22% in 1980. In terms of the total NSF budget, the pre-college share has dropped from 34% in 1959 to its present low of less than 1%.

The NSF support for secondary school science and math has fallen to a negligible level, and the present cluster of national problems in secondary school science and math education can in large part be attributed to NSF's negligence of this component of their Congressionally mandated mission. Figure 7 shows how the decline in NSF support at the pre-college level correlates with declining achievement in science as measured by the National Assessment of Educational Progress. Although correlations do not necessarily mean cause and effect. But coupled with all the other evidence, this correlation may well be as good an indicator of a direct relationship as is the case of smoking and cancer.

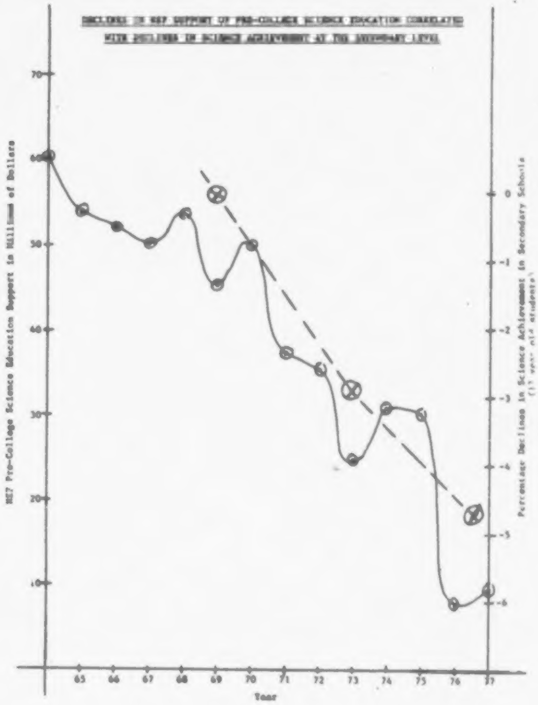
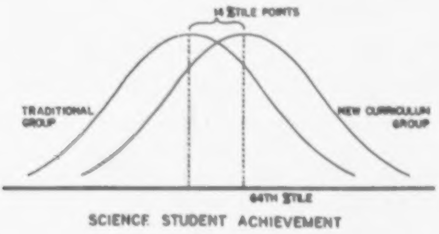


Figure 7

NSF Curriculum Development Projects

Much of the demise of NSF's science education support has resulted from criticisms of curriculum development activities. There are legitimate criticisms that one can make of the "new curricula" produced under NSF support: Those projects often purged applications, concentrated heavily on pure science, and appealed mainly to the very brightest students. Their difficulty level contributed to the reduction in the numbers of students studying science and mathematics in recent years. Yet, according to preliminary results of a very recent project (6), the new curricula were far more successful than most people realized. In this project, an analysis was made of 105 studies involving 45,000 students. Comparisons were made between students enrolled in new science curricula and traditional curricula. On every kind of measure, including achievement, attitude, and process skills, students taking the new NSF curricula scored overall 14% higher. For the BSCS Biology and Chem Study materials, the students scored higher by more than 17%. What is most significant is the fact that students from low socio-economic groups scored 24% higher using new NSF-supported curricula than traditional curricula. Since a larger proportion of our minority population are in the low socio-economic categories, the new curricula, supported by NSF, gave minority children a decided edge over similar children exposed to traditional materials.

EFFECTIVENESS OF NEW SCIENCE CURRICULA



Composite effect of student performance across all new science curricula based on student sample, N=45,000. From Anderson, et al., NSF Grant SED 80-12310.

Figure 8

These studies covered a period of several years in the 1960's and 1970's. Few teachers are left in the schools now who are qualified to teach such curricula, and essentially none have been given the in-service training to do so since NSF abandoned that kind of program several years ago. Also, the materials are badly in need of revision and modification to take into account computers, modern electronics, and applications to technology. The problem of offering appropriate science to less able children also must be addressed.

Comparisons of U.S. and U.S.S.R. Science and Math Education

Recent comparative studies (7) in science and engineering education between the Soviet Union and the United States suggest a major offensive by the U.S.S.R. to increase its economic productivity and defense preparedness through science and engineering education. The U.S.S.R. offers its pre-college students sequences of course material in science and mathematics starting with an intuitive level of understanding. Then students progress to empirical levels; finally, they are ready for the formal axiomatic and theoretical understandings. The actual time spent begins with only a couple of hours per week and changes gradually over three or four years until students spend four to five hours per week in class. Thus the Soviets not only offer all students quantitatively more contact with the sciences and mathematics, they do so systematically to ensure that students progress in a way that matches stages of intellectual development. In U.S. secondary schools, and in colleges, students enter a course in physics or chemistry and are immediately introduced for the first time to the highest levels of abstraction, without any intuitive basis or prior empirical knowledge. Thus many find these subjects hopelessly difficult and fail or drop out. Most students simply avoid taking these subjects, having heard how difficult they are. The lack of application in science curricula and their failure to relate to personal and societal problems and issues further alienate students.

What are the Priority Problems?

The most critical problems are at the pre-college levels, especially in secondary school science and mathematics. Those problems are, in order of priority:

1) Critical shortage of physics, mathematics, and chemistry teachers at the secondary school level;

2) Substantial numbers of unqualified persons are teaching science and mathematics in secondary schools;

3) Most certified science and mathematics teachers at the elementary and secondary levels are badly in need of in-service training;

4) New sequences of science and math courses and materials are needed which match stages of intellectual development of children;

5) Elementary school science consultants are needed who understand science, stages of intellectual development of children, and who know what resources are available;

6) Elementary and secondary schools need access to microcomputers, low-cost supplies, and other resources; and

7) Science curricula need revision, and teachers need training in using new materials and new methods of sequencing content.

Can Low-Budgeted NSF Programs Help Solve Science Education Problems? Are There Too Many Programs?

Among the reasons given for eliminating science education from NSF is one that is specious at best. It takes a form something like the following:

The NSF science education effort had grown into many diffuse, low-funded programs without coherence and were therefore ineffective in dealing with the worsening problems. This argument is usually offered by the very persons who have assisted in reducing the support for science education or by those intent on eliminating science education support for ideological, not economic or even political reasons.

Now consider the facts. The 28 or so "programs" of the Science Education Directorate were not programs any more than are the 28 "programs" listed for the Engineering Directorate in the 1982 NSF Budget document.

Just as Engineering has four main programs with 6 or 7 program elements for each main program, science education had four main programs:

I. Science Personnel Improvement
II. Science Education Resource Improvement
III. Science Education Development and Research
IV. Science Education Communications

The various components fit in a reasonable and coherent way to the program thrusts.

The average science education program element was budgeted at about $2.86 million in 1980. In the 1982 Engineering Directorate, the average of those 28 program elements is budgeted at $2.75 million.

	Science Education Directorate 1980	Engineering Directorate 1982
Main Programs	4	4
Program Components	28	28
Budget	$80 million	$77 million
Average Program Element Budget	$2.86 million	$2.75 million

Table IV

If one looked at the individual engineering sub-elements in 1982, he could easily draw the conclusion that the Engineering Directorate was diffuse and ". . .targeted at specific, limited problems without any very clear connection to a larger conception," a statement made recently by Dr. John Slaughter in referring to science education.

The preemptive NSF reorganization, effective March 21, 1982, eliminated the Science and Engineering Education Directorate, replacing it with an Office of Scientific and Engineering Personnel and Education. Staff have been reduced from over 100 in 1980 to 15. This elimination of the science education mission of NSF, if sustained by the Congress, will have been effected with tacit, if not explicit approval and cooperation by a majority of scientists in and out of NSF whose main concern is to protect research support at all costs. Yet most of the people who have ever heard of NSF or have been directly affected in positive ways by NSF, had contact through NSF science education programs. This abandonment of science education will ultimately prove short-sighted in the extreme.

NSF's 1982 Budget for Science and Engineering Education

Of the $20.4 million appropriated for NSF science education for 1982, $15 million was for graduate fellowships. Some $700,000 was designated to support a "commission," and the balance was used to meet "prior obligations."

Since graduate fellowship support is but another form of support for scientific research, the NSF has essentially eliminated all science education activities. The Administration has successfully forced NSF to abandon one of the missions required by its enabling legislation. It is time that NSF ask Congress either to change the NSF organic act and delete science education from NSF's mission or stop the deception that graduate student support alone is somehow equivalent to support of science education at all levels and proceed with its responsibilities by providing a budget which addresses serious national problems in science education.

The Special Commission on Science and Engineering Education

The only new activity for science education in the 1982 budget was $700,000 to support a special commission on science and engineering education. The NSF spent upwards of $3 million over the past five years for studies at the pre-college level. There is ample evidence of what the problems are and what is needed to solve them. What is now needed is federal action to address documented and serious national problems. Regardless of the potential value of the commission, there can be no justification in waiting 18 months for its recommendations before funding other appropriate science education programs.

If a major problem faced physics research, we would not stop all other physics research while we "studied" the problem. The National Science Teachers Association will assist the commission in every possible way, but we strongly recommend that the Congress provide 1983 funds to attack the most severe of the problems already identified and documented.

The Federal Role--An NSF Science Education Program for 1983

The critical shortage of secondary school science and math teachers cannot be solved in 1983. This is also a problem which must ultimately be solved at the state and local levels. Compensation for science and math teachers must be competitive with those in industry. Even though the federal government cannot solve the salary problem, there are other federal measures which can help reduce the severity of this problem. The long-term shortages can be addressed by stimulating new entrants to teacher training programs in science and mathematics. This can be accomplished through NSF scholarships and NSF-supported programs of publicity on the need for teachers.

Problems of quality can and should be addressed at the federal level. In the short term, the NSF could support summer and academic year courses and workshops for marginally-qualified science and math teachers, so that they may reach some minimal level of qualification to teach the assignments they have been given. NSF has considerable experience with such programs. If they are administered without stipends, they can be extremely cost-effective.

The problem of establishing new sequences of science and math courses to match the stages of intellectual development of children is most difficult to solve. Since this problem is really one of research and development, it cannot be justified by a local school system or a state government. It is appropriately a federal responsibility. The most cost-effective solution would be for the NSF to support development and implementation of a model sequence in two or three school systems. These models would be carefully developed in cooperation and with assistance of scientists and science education experts at universities. Detailed guidelines for establishing the sequence would be prepared and widely disseminated. The NSF might then provide support only for consultant services to schools that chose to implement the approach, using the guidelines which had been developed.

The problem of upgrading qualified science and math teachers can be solved by offering short courses and workshops. The NSF has models of these already in operation and could easily continue these programs.

The need for low-cost supplies and other resources can be addressed by NSF through a program of support for area Science Instruction Resource Centers, modeled after the one created by Douglas Lapp in the Fairfax, Virginia School District. Since teaching resources should be a local responsibility, funds should be provided only for establishing the centers, with a complete phase-out of federal funds over a two-year period.

Microcomputers could be supplied through an NSF program of partial support. Even a level of support by NSF of 25% of the cost could have great leverage in bringing larger numbers of microcomputers into the schools. Again, equipment is a local responsibility, but a small matching federal fund could stimulate great local expenditure. Also, when there is one computer present in a school, the demand increases rapidly, and schools find ways to purchase additional units. Given the availability of in-service programs for teachers, proper utilization could be assured.

The revision of curricula to bring them up to date and to accommodate to the new technology, applications, and societal problems, can be accomplished through conventional, but carefully monitored, curriculum development projects. Such projects are the most easily justified as federal responsibility, since the resulting materials are used throughout the nation.

The problems of elementary school science are immense, but a high-leverage approach, with relatively low cost, would be an NSF program of summer and in-service studies for science consultants. Also, some modest one-time grant support could be provided to school districts that were willing to reinstitute a science consultant program for their elementary schools.

Does the American Public Think that Tax Funds Should be Used by NSF to Support Science Education and Basic Research or Just Basic Research?

The Thirteenth Annual Report of the National Science Board, Science Indicators 1980, dated March 31, 1981, offers much interesting and useful information.

The table below is taken from that NSF report. According to this report to the President, the Public would rank science education second as its choice "to receive science and technology funding from tax money." The Public would rank basic scientific research tenth in its choice to receive such tax money. Science education is even ranked ahead of national defense.

Given clear evidence of public preference for spending tax money for science education over spending it for basic research, and given the Congressional mandate in the organic act of NSF to support science education at all levels, it is most difficult to understand why NSF is forced to ignore this responsibility.

Appendix table 8-10. Areas the public would most like to receive science and technology funding from tax money: 1972-79

Area	Percent in 1979	Rank[1] 1972	1974	1976	1979
Improving health care	50	1	1	1	1
Developing energy sources and conserving energy	48	(2)	(2)	(2)	(2)
Improving education	37	5	4[3]	3[3]	2
Reducing crime	36	3	2	2	3
Developing or improving methods for producing food	23	(2)	(2)	(2)	(2)
Reducing and controlling pollution	22	2	3	3[3]	4
Developing or improving weapons for national defense	16	10[3]	11[3]	6[3]	5[3]
Preventing and treating drug addiction	16	4	4[3]	5	5[3]
Developing faster and safer public transportation within and between cities	13	7	7	7	7
Improving the safety of automobiles	9	6	6	8	8
Finding better birth control methods	9	8	9	8[3]	9
Discovering new basic knowledge about man and nature	8	9	8	10	10
Exploring outer space	6	10[3]	11[3]	11	11
Predicting and controlling the weather	4	10[3]	10	12	12
	(N = 1,635)				

[1] In 1979, respondents were asked to limit themselves to three areas, and slight changes in the wording of some items were made.

[2] "Developing energy sources and conserving energy" was not included in the listing prior to 1979 and "developing or improving methods for producing food" was not included prior to 1976. These areas were therefore omitted from the rankings.

[3] Tied for the indicated rank.

SOURCES: *Attitudes of the U. S. Public Toward Science and Technology: Study III* (Princeton, N.J.: Opinion Research Corporation, 1976), pp. 56-57; Jon D. Miller, Kenneth Prewitt, and Robert Pearson, *The Attitudes of the U. S. Public Toward Science and Technology* (Chicago: National Opinion Research Center, University of Chicago, 1980), p. 137.

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Is the NSF Providing More Science and Engineering Education Support to Graduate Students from Foreign Nations than to American Children?

The answer is yes! Some 90% of all science and engineering graduate student support is from research assistantships. At least 20% of the funds from research grants are used to provide research assistantships. Over 20% of all graduate students in science and engineering are foreign nationals (40% of those in engineering are foreign nationals). If we consider only basic research funding of $5.9 billion, we see that the U.S. Government subsidy to foreign nationals in science and engineering education is more than $200 million. This is more than twice the NSF science and engineering education budget in 1980. Thus, while such nations as Iran, Japan, and Saudi Arabia use their resources to educate their children in science at the pre-college level, the U.S. neglects the science education of its children while providing a U.S. subsidy for graduate education in science for young people from competing nations.

Where are the Funds for Science and Engineering Education?

The Administration's proposed NSF budget calls for a total of $1,072.8 million in 1983, an increase of 7.7% over 1982. Needed science education programs could be financed by holding the total research and related activities budget to a 2% increase instead of the 8.7% increase which is proposed. This will free up $65.5 million for science education activities.

NSF Science and Engineering Education Recommended Program Elements for 1983

NSF Undergraduate Scholarships for Math and Science Teaching (4,000 @ $1,500 each)	$6.0 million
Science and Math Teaching Careers Publications and Dissemination	1.5 million
Tuition, Books, and Materials for Summer and Academic-Year Courses and Workshops (5,000 marginally-qualified teachers @ $2,000)	10.0 million
Model Sequences for Science and Math Courses (3 projects @ $2 million)	6.0 million

Short Courses and Workshops for Upgrading Qualified Science and Math Teachers (10,000 teachers @ $1,000)	10.0 million
Model Science Instruction Resource Centers (50 @ $200,000)	10.0 million
Partial Support Grants for Microcomputers (25% of $2,000 for 10,000 schools)	5.0 million
Curriculum Revision and Enhancement Projects	12.0 million
Programs for Science Consultants for Elementary Schools	5.0 million
TOTAL	$65.5 million
Graduate Fellowships	15.0 million
	$80.5 million

One of the major arguments used to eliminate science education support is that the problems are too great and these NSF funds too small to have a significant effect. Yet this budget, of only $65.5 million would directly affect 19,000 science and math teachers and 10,000 schools. It would indirectly affect another 50,000 teachers and millions of science and math students in their classes. The program elements of the Science Education Directorate have been and can be the most cost effective of all federal programs. They are more competitive than the NSF research program. Where 5 - 10% of science education proposals have been funded, some 30 - 40% of research proposals are funded. The NSF science education programs have been and can be of high quality because they are competitive and have never been administered as entitlements. It is the prestige and high quality of the NSF programs which offer the strongest reasons why NSF and not another federal agency should offer these programs.

Sources

(1) T. G. Howe and J. A. Gerlovich, "National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers," Unpublished Paper, November 6, 1981.

(2) J. N. Akin, "Teacher Supply and Demand: A Recent Survey," (ASCUS, Box 4411, Madison, WI 53711) 1980.

(3) Preliminary results of December, 1981, NSTA Survey of 600 Colleges and Universities with science and math teacher training programs.

(4) Random sample of 2,000 U.S. secondary school principals in December, 1981. Analysis done by Dr. James Shymansky using staff and computers at University of Iowa.

(5) Preliminary results of survey undertaken in January, 1982, by Kathleen M. Donnellan, NSTA Preschool/Elementary School Division Director, Springfield, Massachusetts Public Schools.

(6) Ronald Anderson, James Shymansky, et. al. Preliminary Results of Project NSF SED 80-12310, February, 1982.

(7) C. P. Ailes and F. W. Rushing, The Science Race: Training and Utilization of Scientists and Engineers, U.S. and U.S.S.R., Chapters I, II, (Crane Russak, New York) 1982.

The CHAIRMAN. Dr. Gibson, what is the situation regarding engineering faculties? For instance, what has the University of Virginia had to do to cope with this particular problem?

Dr. GIBSON. Sir, I think you know it is a very serious problem. We have been having at Virginia and across the country a great deal of difficulty in recruiting adequate faculty. In certain fields such as electrical engineering and computer science, the shortage is particularly difficult. There is something between 600 and 1,000 positions open in computer science alone that we have not been able to fill. It is a very serious problem, since we are cutting off even those students who want to study these areas of applied science and engineering. We are now rationing the number of openings. We are telling those students who are interested that we do not have the equipment, we do not have the teachers to permit us to allow them to enter.

The CHAIRMAN. That is amazing.

Dr. Briscoe, thank you especially for your kind words in respect to Senator Kennedy's and my efforts to enact the equal opportunities in science and technology legislation. I still agree that this program is a good one, since it attacks the problem without compromising merit. However, I would like to get your impressions on how this program has worked thus far. I am talking about the equal opportunities in science and technology legislation that we put forward.

Dr. BRISCOE. Well, some of the programs have been extremely successful, although perhaps more limited than we would like to see. For instance, the workshops which have been conducted on college campuses all over the country, the science career workshops to which students and faculty come for 1 or 2 days, have provided a great deal of stimulation and inspiration to both groups, the students and faculty.

Since these have been part of the program for women, the speakers have been women scientists. Then they present the picture of professional women in the sciences to both male and female students. Followups on these workshops have shown that they result in a greater interest in students enrolling in science courses, sometimes in switching their majors. I am very sorry to see that there does not seem to be funding for these workshops.

In comparison to funding for visiting professorships where, as I understood it, $500,000 would send 15 women visiting professors next year to various institutions to do research, for that amount of money we could have 100 workshops which would reach approximately 20,000 women. Now among undergraduates today there are approximately 3 million women, and of them only about 7 percent are science majors. In other words, the other 93 percent of women who are in college, the largest group of women who have ever attended college, had any kind of educational opportunity beyond high school anywhere in the world, a big investment is being put into their education and they are not choosing science and technology.

It is all very well to say that the National Science Foundation will instruct everybody to conduct their programs to encourage women. That is talk. It is not action. It is not doing anything. We need an aggressive program of recruitment. We need programs for minority access, and I understand that one of the very good ones for high school students is not part of the 1983 budget.

Therefore, these are the areas where we are failing to draw more people in, many of whom might become teachers. Approximately 18 percent of the men who are in college are majoring in science, and that is a fairly constant number, so that the only hope of increasing the scientific and technological work force is from this other segment of the population, more than half of the college population, which are women and minorities.

The **CHAIRMAN**. That is good.

I have a number of other questions I am going to submit to each of you individually in writing. We appreciate your effort to be here today and to help us make this record. Hopefully, we can solve some of these problems. The authorization process is one thing; the appropriation process is another, but we will see what can be done. Thank you so much for coming.

Dr. **RUTHERFORD**. Thank you very much, Senator.

[The prepared statement of Dr. Briscoe follows:]

WOMEN AND MINORITIES IN SCIENCE AND TECHNOLOGY

TESTIMONY FOR THE

COMMITTEE ON LABOR AND HUMAN RESOURCES

OF THE

UNITED STATES SENATE

WITH REGARD TO

1983 AUTHORIZATION FOR

THE SCIENCE EDUCATION COMPONENT OF

THE NATIONAL SCIENCE FOUNDATION

PRESENTED BY

DR. ANNE M. BRISCOE
PAST PRESIDENT
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15 APRIL 1982

WOMEN AND MINORITIES IN SCIENCE AND TECHNOLOGY

The following testimony is presented by Dr. Anne M. Briscoe, Past President of the Association for Women in Science (AWIS) and of the AWIS Educational Foundation, and presently Chair of the Women in Science Committee (WISC) of the New York Academy of Sciences. Dr. Briscoe is a member of the faculty of the College of Physicians and Surgeons of Columbia Unversity at Harlem Hospital Center.

In the last decade, there has been an alarming narrowing of the gap between the United States and the other industrialized nations in modern technology and scientific achievement. The proposals of the Association for Women in Science and our colleagues in other professional societies are designed to address the challenge of maintaining the superior position of our country in science, a challenge created in part by the shortfall of scientifically and technically trained personnel. Ten years ago, programs were initiated by the National Science Foundation (NSF) to provide greater opportunities for women and minorities for science and engineering education. These efforts resulted in an immediate and sustained increase in women and minority enrollment in science and engineering programs. For instance, in 1970, only 1.5% of engineering students were women according to the National Center for Educational Statistics; less than ten percent of physical and life scentists were women. By 1980, these percentages had increased to 13.4% and 23%, respectively. The substantial increases in the participation of women and minorities are a direct result of a decade of federally funded programs designed and managed by NSF through grants to individuals and and institutions all over the country. Another decade of predictable,

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adequate funding for NSF programs of demonstrated value will yield great returns on the investment in education and career development by increasing the number of professional women and minority scientists. By minorities, we mean persons of ethnic or racial designations other than white, and all handicapped persons.

The success of such pilot programs demonstrated the existence of a great potential resource of scientists and engineers critically needed in many industries, in academic research, in the armed services, and in the cornerstone of a vigorous scientific community, the teaching profession. This potential source of scientists is the invisible segment of the population: women and minorities, which consists of: 1. Young girls in the schools who need guidance and encouragement to prepare for non-traditional careers; 2. College women who might major in science if sufficiently encouraged; 3. Teachers who need continuing education to acquire modern skills in the sciences and/or basic education for humanities teachers who are teaching science without proper qualifications; and 4. Women wishing to re-enter the workforce who cannot qualify without further training.

Although the pre-existing NSF programs increased the recruitment of women and minorities for careers in science and technology, and diminished the barriers to admission to educational programs, they were not in place long enough to alter patterns of discrimination in employment or provide for career development and advancement. In fact, the Director of the Scientific Manpower Commission has published extensive data showing that in all employment settings (ie. the private sector, the government, and the academic institutions), and in all fields other than entry-level engineering, women are discriminated against in hiring, in salaries for qualifications comparable to those of men, and in professional advancement. Furthermore, the discrepancies

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in salary and rank increase with years of experience. Thus, women are concentrated in the lowest ranks and under-represented in the great research institutions. These circumstances explain the reluctance of women and minorities to choose to enter fields where the prospects of success are poor.

Sexism in science is illustrated by the field of chemistry. In 1978-79 according to data compiled by Sister Agnes Green for the American Chemical Society, there were 4,253 members of the chemistry faculties of the 196 research universities which give Ph.D.'s in chemistry in the United States. Of these, 129 or 3% were women. In that year, 14% of the doctorates in chemistry were awarded to women or 214. Only 50% of these departments of chemistry had any women in faculty rank, and you can count on the fingers of one hand, those which had more than two. But there was a pool of women available because between 1960 and 1979, Ph.D.'s in chemistry had been granted to 3,260 women by those same departments that virtually exclude them from faculty appointments. Biochemistry is slightly better: only 21% of those departments exclude women. However, the pool is larger. In clinical chemistry where approximately one quarter at the professional level are women, the salary differential reported by the American Association for Clinical Chemistry was $6,700, a man with a Ph.D. getting $32,000 and a woman, $26.290. One can only conclude from this brief summary of only one field of science that there is widespread institutional sexism in the world of science.

However, women now constitute 52% of the fulltime undergraduate college population. Never before, anywhere in the world, have so many women been educated beyond secondary school. Billions of dollars are being spent on their education but the investment is not benefiting the nation, either because they are choosing more traditional fields than science and technology, or because there are too few post-graduate opportunities and their education stops short of preparing them for productive scientific careers.

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The result is that only about 25% of American scientists are women, many of whom are under-employed, and only about 4% of engineers are women, despite the superior record of high school girls in science. For instance, for the past three years, the top winners in the nation-wide Westinghouse Talent Search have been young women. Yet, as the National Center for Educational Statistics reported in 1978, of the 2.88 million women in fulltime undergraduate enrollment, only 6.7% were science majors. Of the 3.03 million men undergraduates at the time, 18.3% were science majors.

Well, that is the bad news. The good news is that 6.7% is a substantial increase over the proportion majoring in science a decade ago, and is in large part the result of three NSF programs: namely, science career workshops on college campuses; career facilitation projects for re-entry women, and grants to small liberal arts colleges for laboratory research equipment. A further word must be said of their value in providing both tangible and intangible support for science education and career development of women and minorities.

First, the NSF-sponsored career workshops that have been part of the college scene all over the country, have done more than provide expert advice to the participants. They have been a tremendous psychological boost to women faculty sparcely scattered through the science faculties of our universities. As a speaker at such workshops in West Lafayette, Indiana, in Aurora, New York, in South Hadley, Massachusetts, in Poughkeepsie, New York, in Washington, DC, and in Brooklyn, New York, I have been heartened by the large enthusiastic audiences of students and faculty. Both groups need external stimulation and encouragement. Students need to meet professional women scientists, and that includes male as well as female students, in order to be able to envisage women in those roles. One cannot cite statistics on the exact number of decisions to major in science that

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have resulted from workshop experiences. However, anonymous student evaluations are an accurate reflection of the degree to which the workshops inspired them and met their expectations. Based on these evaluations, it has been clear that even workshops that impinge upon leisure time in beautiful weather have gotten rave reviews.

Of the workshops my committee, WISC, has conducted at the New York Academy of Sciences, one was sponsored by NSF. After the public announcement was distributed, interest in attending was expressed by seven times as many women as the Academy could accommodate. Many were fulltime undergraduates at local colleges, but their campus guidance counselors are not a substitute for scientists actually working in the "real" world. Our recent engineering and computer science workshop, held on a bitter Saturday in the midst of a severe winter storm with travelers' warnings, drew to the Academy 75% of those who had registered in advance, although there was no fee. Career workshops at which speakers come directly from the workplace (ie. from their laboratories) have been so successful and cost-effective that they should be made permanent adjuncts to our educational system. The leadership role of NSF, under the direction of Ms. Joan Callanan, in guiding the workshop organizers, in helping them to avoid costly errors, and in generally teaching them the workshop art, also merits high praise.

Another highly successful NSF-sponsored program has been the long-term career-facilitation project for re-entry women. My participation in some of these has demonstrated to me the great need for them as well as their value in the recruitment of scientists and engineers from a new "pool".

Finally, there is the program to provide research equipment to small colleges. For a statement that is representative of the effectiveness of these grants, I have included part of a letter from the Director of the

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Science Center at Wellesley College in Massachusetts, Professor R. Steven Schiavo:

"The NSF programs have been particularly useful for small liberal arts colleges, such as Wellesley, since at these institutions undergraduates (as opposed to graduate students) typically work with faculty as research assistants. This opportunity to do research in a colleagial relationship with role models is an important support for a student's career orientation and development of self confidence. There are also benefits in that at these institutions research equipment is usually available to students for their independent study and Honors research. For example, our faculty members' success in the Two and Four Year College Research Instrumentation Program has meant that our students gain experience with up-to-date instrumentation. As a consequence, the students' interest in pursuing graduate training in the sciences is heightened and their candidacy for admission to advanced programs is also strengthened.

Similarly the ten year success in obtaining NSF-URP awards by our Biological Sciences Department has meant that a number of students have gained invaluable laboratory experience. This program has helped foster all students' expectations that participation in research is a regular and common part of their education. About 90% of the students who have participated in the URP program have gone on to advanced training."

To summarize the problems and the solutions: First the problems:

1. The national shortage of scientists and engineers.
2. Insufficient educational opportunities for women and minorities. in science and engineering, graduate and undergraduate.
3. Insufficient sources of financial aid for women and minorities for undergraduate and graduate study in science and engineering.
4. Unequal opportunities for career advancement for women and minorities discouraging them from choosing science careers.
5. Unequal opportunities for recognition of achievement for women and minorities.
6. Inadequately trained science teachers.
7. Invisibility of women and minority scientists resulting in an absence of role models needed to overcome traditional patterns of career choices by women and minorities.

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WOMEN AND MINORITIES IN SCIENCE AND TECHNOLOGY

To summarize the solutions:

Appropriation by Congress of adequate resources to fund NSF programs for:

1. Career workshops at all levels: junior and senior high school, college and re-entry.
2. Retraining and continuing education for elementary and high school teachers.
3. Visiting professorships for women and minority scientists.
4. Undergraduate scholarships for women and minority science majors.
5. Graduate fellowships for women and minorities in the sciences.
6. Research grants for women and minorities to initiate research careers.
7. Grants for modern laboratory equipment for colleges to facilitate teaching and undergraduate research, with special support for minority institutions.
8. [illegible]

To accomplish these goals, AWIS, [illegible] respectfully make the following recommendations to the U.S. Senate Committee on Labor and Human Resources:

1. Restore the funding for National Opportunity grants to [illegible] million.
2. Provide a minimum of [illegible] million for Visiting Professorships for Women.
3. Provide [illegible] million for Minority Research Initiation.
4. Provide a minimum of [illegible] million for Research Improvement in Minority Institutions.
5. In general, support at the same level, the provisions of HR [illegible] that is now under consideration by the House of Representatives.

In conclusion, AWIS and the [illegible] would like to express their appreciation to Senator Hatch for the opportunity to participate in these hearings and for his support of legislation to increase opportunities for women and minorities who aspire to careers in science and technology.

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WOMEN AND MINORITIES IN SCIENCE AND TECHNOLOGY

We would also like to commend the Subcommittee on Women in Science and Technology of the NSF for the leadership role it has assumed in implementing the provisions of the Science and Technology Equal Opportunities Act.

Respectfully submitted,

Anne M. Briscoe
Anne M. Briscoe, Ph.D.

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WOMEN AND MINORITIES IN SCIENCE AND TECHNOLOGY

SOURCES

Publications of the National Research Council:

"Climbing the Academic Ladder - Doctoral Women Scientists in Academe"

"Survey of Doctoral Recipients"

Publications of the American Chemical Society:

"College Chemistry Faculties", 4th edition

"The Directory of Graduate Research"

Publication of the National Center for Education Statistics:

1978-79 Education Directory of Colleges and Universities

Publication of the Scientific Manpower Commission:

Manpower Comments, Volume [illegible], No. [illegible], [illegible], [illegible]

Clinical Chemistry salary data was supplied by the Director of Financial and Accounting Division of the American Association for Clinical Chemistry.

The CHAIRMAN. Our final panel today will be headed by Dr. E. Margaret Burbidge, president of the American Association for the Advancement of Science, and director of the Center for Astrophysics at the University of California in La Jolla, Calif. She will be accompanied by Dr. F. Thomas Juster, on behalf of the Consortium of Social Science Associations and director of the Institute for Social Research at the University of Michigan in Ann Arbor; Dr. William S. Partridge, president of the University of Utah Research Institute in Salt Lake City; Dr. Lawrence Berkowitz, on behalf of the Association of American Universities, and provost, Clark University, Worcester, Mass.; and Dr. Robert Parry, who is president of the American Chemical Society and distinguished professor of chemistry at the University of Utah in Salt Lake City, Utah.

Dr. Burbidge, we are happy to welcome you here with your colleagues and we are delighted to take your testimony at this time. I might mention that I have to leave in just a few minutes but I wanted to introduce this panel. Senator Hawkins is going to come and chair the hearing; she shares my interest in NSF. If you see me leave it is not because of a lack of interest. It is because I have another commitment I have to keep downtown. It happens to be with the American Bar Association Board of Governors.

We are happy to have you here today and appreciate your testimony.

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STATEMENT OF DR. E. MARGARET BURBIDGE, PRESIDENT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, ACCOMPANIED BY DR. F. THOMAS JUSTER, ON BEHALF OF THE CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS; DR. WILLIAM S. PARTRIDGE, PRESIDENT, UNIVERSITY OF UTAH RESEARCH INSTITUTE, SALT LAKE CITY, UTAH; DR. LAURENCE BERLOWITZ, ON BEHALF OF THE ASSOCIATION OF AMERICAN UNIVERSITIES; AND DR. ROBERT PARRY, PRESIDENT, AMERICAN CHEMICAL SOCIETY

Dr. BURBIDGE. Mr. Chairman, thank you very much for inviting me to be with you today. For a short summary, I will present highlights of my written testimony which has been submitted for the record. I will quickly cover six topics and then respond to any questions that can be addressed.

The first point, a positive one, is that the United States still has overall the strongest scientific and technological enterprise in the world. On pages 2, 3, and 4 of the testimony, I note that the administration has requested $44.[illegible] billion for R&D in fiscal year 1983. This amount results from the growth rate of about 10 percent a year before inflation is accounted for. In the aggregate we spend more for R&D than Japan, West Germany, and France combined but then we have to recognize that this is in the overall much larger economy.

In people resources we have the largest number of scientists and engineers, and we continue to dominate the Nobel awards in science, although of course these are often given for work done many years ago.

As for trade, we sell about nine times more technology than we buy and we have favorable trade balances in R&D-intensive products with all of our main trading partners except West Germany and Japan.

This is not a picture of collapse, and it is reassuring that the Reagan administration has endorsed a strong Federal commitment to support R&D.

Next, my second point, maintaining this scientific and engineering strength with appropriate balances is central to reinvigorating our economy and providing for our national security. In the testimony I cite research results which suggest that technological advance or the growth of knowledge has been a powerful source of economic growth over both short and long periods since 1929.

It would appear that investment in building knowledge for the future in science, technology, and education appears to be at least as effective as investment in capital stock in powering economic growth. Public policy decisions should reflect this factor.

As a cautionary note about economic growth, we need to remember that the really large increases for R&D in recent years have been for defense, and particularly for weapons development. It is very much an open question as to how much transfer to private and long-term economic growth results from such development expenditures.

Another disturbing feature is that in both the public and private sectors in this country we have enormous pressures for short-term payoff, and this is a terribly serious problem for research and for the country. It may well be the best explanation of our productivity problems and our flagging international competitiveness.

My No. 3 point is that there are reasons to be concerned that our strength and relative position in the world may be in some jeopardy, and in the testimony I outline a number of major concerns. While R&D totals are up, the fiscal year 1983 increase due to inflation is only 2.2 percent real growth since fiscal year 1981, and as noted above, defense R&D accounts for nearly all of this growth. Indeed, there are real declines in nondefense R&D of about 6.6 percent since fiscal year 1981.

Among statistical indicators of acute problems are these: We are dropping in our world market share of R&D-intensive products—31 percent in 1962 to 21 percent in 1977. Relative to most other countries, we devote far less of our resources to civilian R&D, mostly because of the military R&D expenditures. R&D expenditures as a percentage of the gross national product have been declining since the mid-1960's, while other countries are increasing this ratio. In industry, research investment as a percentage of sales has decreased by one-third between 1968 and 1980. Clearly we need to focus on the reasons for such trends and devise appropriate responses.

My fourth point: Science and engineering is an integral part of our scientific and technological structure in the United States, and there are reasons to be greatly concerned here, as you have been hearing in the previous testimony. On pages 11 and 12 of my testimony, I point out that last month at a consultation of presidents of the AAAS affiliated societies, a question was put by a senior Senate staff member, "What is the major concern of the audience?" The consensus reply was, "Science education at all levels."

The central requirement that I put before you today is not a shopping list of specific suggestions. Rather, it is a call for national leadership and a new national commitment to excellence in science and engineering education, and I think it will be natural for the NSF to be in a leadership role both for its past record and as a result of the deliberations—which I hope will be successful—of the new commission which you have heard about in the testimony by Dr. Slaughter and Dr. Branscomb. I think those in the Congress and the scientific community who helped formulate the original charter of the NSF were correct in assigning both research and education roles to the Foundation because they are inextricably mixed.

Finally, to expect scientific and technological progress while abandoning or drastically curtailing efforts at national or local levels in improving science and engineering education in our schools, is a disservice to the Nation's interests.

My fifth point is that disquieting controversies are taking place between Government and science which may have negative impacts on our future. However, first I would like to acknowledge the willingness that key officials both in and out of the White House have displayed in working on these problems.

One of these problems is the question of scientific communication and national security. The ongoing debate on classification of certain basic research seems to have a temporary solution in Executive Order 12356, issued by the President on April 2. However, this debate will continue as we face how best to balance certain national security interests which call for limitations on scientific communication and other interests which strongly argue for open communications among scientists.

This latter point of view is strongly endorsed in a AAAS council resolution adopted in January 1982 and it is a point of great concern to the leaders of many of our forefront research universities.

The next problem or controversy is the question of guaranteed student loans. On page 14 of the testimony I mention a looming problem of great magnitude. It is the proposed change in guaranteed student loan eligibility. If graduate students are not allowed to participate, we believe there will be a significant damage to advanced scientific and engineering education.

Another problem area: paperwork and regulation. The debate on OMB circular A-21 is noted in my testimony, and this subject deals with accountability, paperwork, and regulations. Dr. Partridge is here to discuss this further if you wish but there is no doubt that a serious dilemma exists: how to balance accountability, which we all recognize as a necessity, against moving too far with strangling paperwork and controls that impede research unnecessarily. I can comment further on this in the questions, if you wish.

Finally, my last point, my sixth point: my comments on the NSF budget request for fiscal year 1983. Beginning on page 16 of my testimony, I refer to a question put to us by the committee which asks whether the NSF budget request is in the ball park. Well, my short answer is a qualified yes in the context of a political and economic environment which augers poorly for budget increases but there is a longer answer, too, which suggests some realinements and a modest increase to cope with certain problem areas which I will now touch on.

Because we see a budget which at a total of $1.073 billion, has a small overall real growth, there are real growths in the natural and physical sciences but real declines in most of the policy, behavioral, social, economic, and information sciences. From this budget science education has been virtually eliminated. This budget has no major initiatives for equipment and instrumentation and overall, the budget is in a holding pattern while our economic problems get sorted out. In real terms it is a budget 6 percent less than fiscal year 1981.

Again, turning to several specific areas, I note that of particular concern is the reduction of an already small NSF program for international cooperation in science from $10.6 million to $9.1 million. International cooperative and international people involvement are essential elements of scientific progress.

Again, another point, the instrumentation inadequacies strike at the heart of our capabilities to conduct frontier research and to teach effectively in universities and high schools. We are definitely, as other people have said today, we are definitely in a negative growth situation here. Dr. Berlowitz can discuss this question in general, this general situation, if you wish.

The question of women, minorities, and the handicapped, the NSF has played a leading role in working on the problems of these special groups with respect to education and careers in science and engineering. However, two points: The elimination of science education will strike severely at a number of efforts in these areas, and the elimination of support for research to aid the physically handicapped is not easy to understand.

On the other hand, one can be pleased that certain women's and minority programs have been increased and retained in the NSF: for example, the visiting professorships for women, minority research instruction and improvement for minority institutions. However, I do have some serious concerns on the magnitude of this and the effort that is needed to draw more than the less than 10 percent of women into the sciences.

Engineering research, which I address toward the end of the written testimony, this area remains at least 10 percent of NSF's research equipment and instrumentation endeavors, so questions continue about the balance between engineering and other research areas. Of particular concern are the social and behavioral sciences because support for these areas at the fiscal year 1982 level, this is an improvement over the situation last year. Dr. Juster is here to add his comments on these areas of science but I would simply note that many of the Nation's problems dealing with energy, the environment, health care delivery, productivity, and economic development call for continued research in the social and behavioral sciences as well as in the engineering and physical sciences. The social sciences deal with the framework in which we all operate.

A last point: the graduate student fellowships. It is a positive move by NSF to increase fellowship stipends from $4,500 per year to $6,500. However, perhaps a more accurate reflection of attractive stipends is the Defense Department level which is $12,000, with $8,000 going to the university versus NSF's $4,000 going to the university.

Conclusions and recommendations: Again, all of us here thank you, Senator Hawkins, for the opportunity to express our views and for your own roles in supporting investment in science and technology. Just to summarize this rather long testimony: One, we may have tilted too far in the direction of the military research and defense buildup insofar as balance with civilian R&D is concerned. Two, we need to push for greater recognition of the role of R&D in economic development. Three, greater national attention must be focused on what I believe to be very harmful, this short-term payoff syndrome. Four, a new national commitment and statement of national leadership is required in science and engineering education. Five, graduate students should not be eliminated from guaranteed student loan programs.

Finally, while staying close to the President's budget request, I would suggest a few realinements and a modest increase to cope with the problems outlined for you above.

Again, thank you very much for inviting me.

[The prepared statement of Dr. Burbidge follows:]

Statement by

Dr. E. Margaret Burbidge

President

American Association for the Advancement of Science

on

The Fiscal Year 1983 Budget Request

for the

National Science Foundation

Before the

Committee on Labor and Human Resources

U. S. Senate

Dirksen Senate Office Building

15 April 1982

Introduction

Mr. Chairman and Members of the Committee:

Thank you for inviting me to be with you today as you consider the NSF budget request for Fiscal Year 1983.

First, let me say that my role today is a difficult one. Although I am appearing as the President of the American Association for the Advancement of Science, the views expressed are my own. And while I am here as a sort of "consensus spokesperson," I do not wish to convey the impression that I can fully portray the rich diversity of opinion held by the millions of members of our Nation's scientific and engineering communities. Yet, I would hope that a number of my comments would be generally--if not totally--accepted by my fellow scientists and engineers.

Overview

As a general overview, let me summarize several points which I will expand on later in my testimony.

(1) The United States still has, overall, the strongest scientific and technological enterprise in the world.

(2) Maintaining this strength is central to reinvigorating our economy and providing for our national security.

(3) However, there are reasons to be concerned that our strength and relative position in the world may be in some jeopardy.

(4) Science and engineering education are integral and vital parts of our scientific and engineering structure--but we face some serious problems.

(5) Disquieting controversies are taking place between government and science which may have certain negative impacts.

(6) Finally, you asked if the NSF budget request is "within the ballpark;" it is when one considers the current economic climate, but there are some quite special issues which trouble me and call for close attention.

(1) The United States still has, overall, the strongest scientific and technological enterprise in the world--but, as will be discussed later, we do face serious problems.

During 1981, the total national R&D effort was roughly 70 billion dollars, of which about half was provided by the Federal Government. As one looks at the overall picture for Fiscal Year 1983 we see that the Administration has requested about $44.4 billion in new budget authority for federal R&D--up from $40 billion in Fiscal Year 1982 and $37.3 billion in Fiscal Year 1981.

These are growth rates in current dollars on the order of 10 percent per year--that is, before inflation is accounted for. Such numbers are very large and, in the aggregate, the U. S. is outspending Japan, West Germany, and France combined. As a note of caution, these large numbers cannot be examined in isolation. For example, as observed in the Science and Technology report of the Commission on an Agenda for the Eighties, "the sheer size of the U. S. economy results in larger R&D expenditures than those of other countries."

Also, we have the greatest number of R&D scientists and engineers and the highest proportion of such people in the labor force of any country except the Soviet Union. Such numbers are also reflected in the continuing dominance of Americans in Nobel awards in science, although one needs to remember that such awards are more often rooted in research done many years ago.

In the trade sphere, we can point to the fact that the United States sells about nine times more technology than it buys. Also, the United States enjoys a favorable trade balance in R&D-intensive manufactured products with all its major trading partners except West Germany and, in particular, Japan.

This is not a portrayal of a system in a state of collapse. Our record of achievement in science and technology remains impressive by any standard of measurement. It is a record which rests on decades-long support by generous taxpayers and understanding politicians from all points of the political compass.

And it is reassuring that the Reagan Administration has reiterated and endorsed a strong federal commitment for the support of research and development. Given the current severe constraints on budget decisions, it is clear that effective advisers within President Reagan's inner councils also recognize the fact that support for science and engineering is a worthwhile investment in our future.

(2) Maintaining this scientific and engineering strength with appropriate balances is central to reinvigorating our economy and providing for our national security.

Economists and those in other disciplines as well have given increasing attention to understanding the factors that contribute to economic growth. For example, Edward Denison, Edwin Mansfield and others have reported research results which suggest that technological advance, or the growth of knowledge, has been a major source of economic growth over both short and long periods since 1929.

Such findings have powerful implications for policy--both in the public and private sectors. To get right to the point, investment in the building of knowledge for the future--in science, technology and education--appears to be at least as effective as investment in capital stock (production equipment, tooling, and physical plant) in powering economic growth. Yet, as I will show later, we are currently investing a smaller fraction of our resources in our future than at any time since the mid-1950's. Those of you in a position to shape national policy may well wish to consider the implications of these ideas for an entire range of tax and budget issues now before the Congress.

As I will discuss in more detail shortly, the significant budget increases of the past several years for national security have included large increases for military R&D Yet, these very large increases are for the most part being allocated to weapons development. And, I would argue that it is very much an open question as to how much "transfer" to the private sector and long-term economic growth results from military R&D, especially from weapons development. Finally, less than one-eighth of the FY 1983 $4.2 billion increase for defense R&D goes for basic and applied research--the areas most likely to have positive effects on the academic research world and the general economy.

My point is that we need to remember that while Federal R&D has increased in recent years, most of the growth is attributable to large increases indevelopment expenditures for weapons systems. Thus, we must be exceptionally careful about assuming that "all is well" because aggregate Federal R&D amounts are increasing at rates rather better than for most non-defense programs.

In my lead observation I used the phrase "with appropriate balances." One dimension of such "balances" has already been alluded to in my review of defense R&D; close attention must be given to the defense/non-defense balance of R&D since real increases are almost exclusively in the defense area, where most of the focus is on short-range investment (development) and less is on the longer-range (research).

This leads to another aspect of balance: time. In both the public and private sectors in this country we have enormous pressures at work for short-term payoff. This is quite antithetical to the time constants of an effective research program. For example, the production of a PhD. scientist or engineer is a 5-7 year endeavor which cannot easily be turned on and off. Also, these short-term pressures work against stability in research goals and programs. Most scientists would argue that reasonable stability is a firm requisite for an effective national research endeavor. I consider this "short-term syndrome" to be a terribly serious flaw in our basic thinking, our reward systems, our policy structure, and the ways we work and live.

A case in point was cited recently in the Wall Street Journal (February 5th) in which it was reported that U. S. corporate research in the steel industry lagged behind thet of Japan mainly because of U. S. "proclivities" for short-term payoffs. It was argued that financial pressures worked against the long-term orientation needed for successful scientific work. The report's authors stated that these shortcomings are shared by other large U. S. companies.

Leighton Smith, an Arthur Anderson & Co. partner with long experience in Japan, argues that labor relations are important but that the key to Japanese success is their orientation to a long-range point of view. Smith claims that until U. S. boards of directors stop worrying about this quarter's results and free up management from "fire-fighting" to concentrate on markets down the road, American industry's markets will continue to be eroded by the Japanese.

All of this leads me to the conclusion that federal and private support of R&D has been and will continue to be the most important investment in our future. Collectively we must determine how better to select and choose among investment alternatives, public and private; and especially we must be more patient and sensitive to the time dimensions of our investment decisions. We are literally betting our future on how well we make them.

(3) There are reasons, however, to be concerned that our strength and relative position in the world may be in some jeopardy.

Let me begin this part of my analysis with several highlight observations of important R&D trends:

(a) Earlier I cited total Federal R&D totals of $37.3 billion in FY 1981, $40.0 billion in FY 1982, and a projection of $44.4 billion for FY 1983. Taking the effects of inflation into account, the real (constant dollar) increase for 1983 is 3.9 percent over 1982, but only 2.2 percent over 1981.

(b) A large increase in defense R&D (up 18.9 percent in current dollars, 11.0 percent in constant dollars over FY 1982) accounts for nearly all of the growth in total R&D; non-defense R&D is nearly level in current dollars and down somewhat (-6.6 percent) in constant dollars.

(c) Basic research increases from $5.1 billion in FY 1981 and $5.3 billion in FY 1982 to $5.9 billion in FY 1983. This represents a two-year increase of [illegible] percent in current dollars (and a [illegible] percent decline in constant dollars). Increases in basic research are widespread across the government, but for the most part at rates below those required to keep pace with inflation. Also, there are significant support variations by fields of science--with relatively large increases for some and declines for others.

(d) The characterization of social and behavioral research as "lower priority," which stood out in last year's budget, is noticeably absent from this year's justification documents. On the other hand, there are few--if any--increases over the amounts Congress added back during review of the FY 1982 budget.

And in certain parts of the government--such as the Alcohol, Drug Abuse and Mental Health Administration--the social and behavioral sciences have been virtually wiped out. Such decisions are rather hard to understand given the vital role that the social and behavioral sciences play in a wide range of society's problems. Also, within NIH, what is internally called a "Social Review Committee" has been established to conduct a special review for social science research proposals; this is a process that proposals in other disciplines do not encounter.

(e) As a summary point, apart for defense R&D (and two other minor exceptions) all agencies of the government will experience an actual (i.e. constant dollars) reduction in R&D funding from FY 1981 to FY 1983.

Such trends necessarily temper one's optimism about the stronger view that total federal R&D is growing at a healthy pace. And there are other trends which can only be characterized as deeply troubling:

- The fraction of scientists and engineers in the U. S. labor force (while large as I noted earlier) has declined since 1965; however, since that time this fraction has doubled in both Japan and West Germany and increased significantly in the Soviet Union.
- Over the past decade, the United States has experienced slower growth rates in manufacturing productivity than have most industrialized countries.
- Although the U. S. still has an overall competitive advantage in R&D-intensive products and technical information, there has been steady erosion of that position: the U. S. share of the world market in these products dropped from 31 percent in 1962 to 27 percent in 1970 and then to 21 percent in 1977.
- Compared to Japan and West Germany, we invest relatively far less of our resources in civilian R&D which is directly oriented toward economic and social needs as well as to the search for new knowledge. One reason is rather obvious. In recent years Japan has allocated only 2% of its governmental R&D expenditures for national security and defense; West Germany has allocated about 12%; meanwhile, we have been investing about 50% of our R&D funds in this sector and this fraction is

growing. We are carrying much of the defense load for the western world. World military expenditures now are at the level of $550 billion annually and this is growing at a rate of more than $50 million per day.

- Our total expenditures on R&D, considered as a percentage of our Gross National Product, have been declining steadily since the middle 1960's--from 2.96% in 1964 to 2.37% in 1981; we *may*, however, have the first slight upward trend beginning in 1980. In contrast, the Japanese percentage in this same period has risen from 1.48 to 1.93% and the West German percentage from 1.57 to 2.36%--now about equal to ours.
- Investment by U. S. industry in research, as a percentage of U. S. industrial sales, has decreased by one-third between 1968 and 1980.
- Indeed, we are currently investing a smaller fraction of our resources in our future than at any time since the mid-1950's. This must be a source of serious concern.

Consideration of these trends and comparisons provide some rather disturbing insights about what has been happening to our investment in the future. Clearly there are signs of leadership erosion which cannot be ignored.

In summary, despite large levels of R&D funding, our R&D investments are declining relative to others--and more and more of our support goes to military R&D. Despite the lack of a firm statistical linkage between the leveling of real growth in R&D since the late 1960's and our productivity slow-down, I feel confident in pointing to the need for continuing substantial R&D investment--public and private --for the long-range well-being of our nation. Given the technological successes of some of our international competitors, we can ill afford to follow a policy of "no real growth" in R&D over the long term.

(4) Science and engineering education is an integral part of our scientific and technological structure in the U. S.--and there are reasons to be greatly concerned.

While Dr. Rutherford and others have already testified as to the gravity of problems facing us in science and engineering education, I would like to add several comments.

Last month at a Consultation of Presidents of AAAS Affiliated Societies, a question was asked by a senior Senate staff member: "What is the major concern of the audience?" The consensus reply was "science education at all levels." Of special concern, too, is the engineering faculty crisis. We cannot wait several years for new studies to be completed; the problems have been accurately identified and so have many solutions. What is lacking is a consensus among key parties on basic policies and frameworks.

The central requirement that I put before you today is not a shopping list of specific suggestions. Rather, it is a call for national leadership and a new national commitment to excellence in science and engineering education. And I think it would be natural for the NSF to be in a leadership role as a result of the deliberations of the new Commission described to you by Dr. Slaughter.

I think that those in the Congress and the scientific community who helped formulate the original charter for the NSF were correct in assigning both research and education roles to the Foundation. Finally, to expect scientific and technological progress while abandoning or drastically curtailing efforts at national and local levels at improving science and engineering education in our schools is unrealistic and a disservice to the Nation's interests.

(5) Disquieting controversies are taking place between government and science which may have negative impacts on our future.

Controversy is inevitable in a complex, free society and I do not raise several important issues in an adversarial way. Indeed, the issues are not new and extend back over decades.

And whether one agrees or disagrees with specific Administration positions, I would like to acknowledge the willingness that key officials in and out of the White House have displayed in trying to work out satisfactory resolutions to these problems. Several such problem areas are discussed below.

Scientific Communication and National Security: An acute dilemma confronts the Federal Government and the scientific community concerning scientific communication. On the one hand, knowledgeable individuals in government believe that free availability to foreign nationals of certain unclassified research results in specific fields poses a threat to national security. Therefore, they think it is essential to limit such foreign access through control of the export of scientific information.

On the other hand, large majorities of scientists and engineers in academia and elsewhere believe that open communication is an essential element of a creative environment. This point of view was strongly endorsed in a AAAS Council resolution adopted in January 1982. In such a view, restrictions on communication would sap the strength and vitality of the educational and scientific endeavors upon which our technologies and our national defense are based.

On 2 April, Executive Order 12356 was issued by President Reagan. This Order deals with a wide range of classification and access issues and, after considerable debate, an exemption for basic research from general classification requirements was maintained. However, I do not expect the debate to end with the issuance of the President's Order, although I think it is a step in the right direction.

Thus, I would strongly support continuing study of this issue and all of its ramifications. One mechanism for such a study is the National Academy of Sciences Panel on Scientific Communication and National Security. This Panel has been established on the basis of the following rationale: a balanced and objective assessment of the opposing views is both necessary and timely. The interdependence of government and the research community in advancing science, technology and national security requires the prevention of a serious breakdown of mutual confidence.

I would also like to acknowledge a significant step forward in defense-university relations. A "DOD-University Forum," co-chaired by Don Kennedy of Stanford and Richard DeLauer, has been set up to provide ways for on-going discussion of a range of issues of mutual concern. Members include eight university presidents and a comparable number of senior defense officials.

Guaranteed Student Loans: A looming problem of great magnitude is a proposed change in guaranteed student loan eligibility. If graduate students are not allowed to participate, we believe there will be significant damage to advanced scientific and engineering education. This may well be one of the most important issues in education now before the Congress. We would urge that favorable consideration be given to retaining graduate student participation.

Paperwork and Regulation: A decades-long debate surrounds the topic of research administration and regulation--particularly in the universities. No sensible scientist will object to reasonable requirements for accountability of public funds provided for research;

however, an exorable trend over the years has been toward more reporting, more accountability, and more regulations.

It is not my intention today to discuss specific features of this problem; only its general outlines will be touched on. Clearly we must balance the requirements of administration with the attendant costs--and with research not done. By "research not done" I mean there has been a distinct and widespread shift in personnel allocations in universities toward hiring administrative people rather than research support.

Important questions emerge: How much accountability is deemed necessary to protect the public interest? Is there evidence of widespread abuse of trust? (The answer is no.) What are the forces that push for more accountability? Are there special characteristics of research that do not fall easily into a framework of time-clocks and detailed records? There are certain underlying attitudes expressed in the pressures described above which suggest less than a full comprehension of important characteristics of research. For example, let me draw upon my own work--which is not unlike that of other scientists--and say:

- Research and teaching are tightly intertwined in the university and separating them is often a very artificial process.
- Reporting forms are based on the 40-hour week and I cannot remember very many such weeks during my research and technology career.

On the other hand, I do not wish to leave this topic with what may seem to be negative reactions. There is a general belief that good progress is being made in discussions and negotiations with the government--and in particular with the Office of Management and Budget on revisions to OMB Circular A-21, "Cost Principles for Educational Institutions."

(6) Response to the NSF Budget Request for FY 1983

A question put to us by the Committee asks "if the NSF budget request is in the ballpark?" My short answer is a qualified "yes," in the context of a political and economic environment that augers poorly for budget increases. But there is a longer answer too.

One sees a budget with these contours:

- At a total of $1,073 billion, there is an overall increase of 7.7 percent over the FY 1982 level of $996 million.
- There seems to be a general strategy of increasing the average size of research awards by some selective decreases in their number. This will result in an estimated 3-6 percent reduction in the number of scientists supported and some reduction in the number of graduate students supported.
- Quite likely we will see further strains on the NSF as more proposals get shifted from other agencies to the NSF as a result of budget pressures except in defense.

- There is about 3 percent real growth in the mathematical, physical sciences and engineering programs; about 2 percent real growth for the astronomical, atmospheric, earth and ocean sciences and a smaller increase in biological sciences.
- There are real declines in most behavioral, social, economic and information sciences--with programs being generally held to FY 1982 levels or cut below such levels.
- There are no major new iniatives in R&D equipment and instrumentation.
- Science education--as you have already heard in the previous testimony--has been virtually eliminated.

When one compares the overall increase between FY 82-FY 83 for the NSF basic research (7.7 percent) with the increase in DOD basic research (21.2 percent), it is a little difficult to accept at face value the Administration's description that the Budget "reflects the high priority given NSF programs" in achieving the goals of "a strong foundation for the nation's future economic and social well-being."

Let there be no mistake, this is a budget in a "holding pattern" while the Nation's economic problems are sorted out. It is a budget that has increased by 3.0 percent between FY 1981 and FY 1983 (after the 1981 rescission); hence, it is a budget that shows a cut of about 11 percent in real dollar terms since 1981.

Now, let me turn to a number of what I think are some special problem areas:

International programs: Of particular concern is the reduction in an already small NSF program for international cooperative activities in science--from $10.6 million to $9.1 million. For example, the elimination of support for international scientific organizations and for the international travel grants program will lead to a lessened presence of U. S. scientists--particularly younger ones--in international activities.

And as for the elimination of support for the Institute of Applied Systems Analysis in Austria, this is a measure which seems to have origins in factors other than scientific merit. All in all, at a time when foreign science is becoming more advanced and more competitive, it is imperative that as a matter of self interest we maintain close contacts so as to know what is going on.

More generally, international cooperation in science can make an essential contribution to the goal of economic development by increasing the opportunities for applying science and technology to the innovation process. It can also enhance our security by strengthening alliance relationships and by assisting other countries to achieve economic progress with political stablity.

Instrumentation: In its budget documents the NSF accurately states that "much research today is instrument-dependent and many advances can only be made through improvement of instrumentation. Investment in research instrumentation is an investment in the future growth and productivity of modern science and engineering."

In contrast to this statement one must place the following finding on the state of instrumentation in our research universities, based on reports prepared under the auspices of the American Association of Universities in 1980 and 1981:

> The growing obsolescence of research instrumentation in the nation's universities is a problem not just for the universities themselves, but for the nation as a whole. To the extent that such obsolescence impedes the progress of fundamental research at the university, its effects will be felt in such areas of application as agriculture, medicine, biotechnology, engineering, energy, industrial productivity, and national defense. Since over half of U. S. basic research is carried out at univesities, a decline in the research potential of these universities will result in a significant decline in the general rate of scientific advancement.*

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*L. Berlowitz, R. A. Zdanis, J. C. Crowley, J. C. Vaughn. "Instrumentation Needs of Research Universities," Science. 6 March 1981, p. 1017.

Deferral of previously planned initiatives to upgrade obsolete instrumentation carries with it very high risks of further leadership erosion in research. It is difficult to be optimistic about early solutions to this serious problem when the NSF projected support for FY 1983 of $95.3 million (for major equipment, other equipment and instrumentation) is a slight increase of less than $2 million over the 1981 amount of $93.4 million. Also, in the instrumentation area, price increases well above inflation are quite general due to the increasing sophistication required in almost every field of science.

On the positive side, it is true that Dr. Keyworth organized and chaired an Interagency Working Group on University Research Instrumentation during the past year. It is to be hoped that such endeavors will lead eventually to recommendations commensurate with the gravity of the problem.

Another facet of the instrumentation question is not as often talked about. We face comparable inadequacies at the college undergraduate level and in high school teaching facilities. In the past, the NSF has provided limited but effective support for these areas, but the termination of the Science Education Program has ended these modest efforts. Under no circumstances can this be considered a step forward in solving our Nation's problems; more directly, it is short-sighted.

Women, Minorities, and the Handicapped: The NSF program to support basic research in science and technology to aid the physically handicapped is proposed for elimination in the FY 1983 budget. We hope that the Congress will reconsider this action in view of the importance of this program as we seek to tap the potential of science to improve the quality of life for disabled persons. It is difficult to envision such interdisciplinary research measured on its merits as science, as well as its potential applications, being supported through regular programming. Nowhere other than in the NSF is there the support for this kind of basic research effort. With the elimination of Science and Engineering Education, programs focused on career access for disabled persons were eliminated as well.

The professional and related workforce of this country is approximately 9.5% minority and over 40% female. Yet women are only around 9.4% of all employed scientists and engineers; Blacks, Hispanics and American Indians are less than 2% of all employed scientists and engineers. These groups, along with physically disabled persons, represent between 60% and 70% of the U. S. population, a segment so large as to deserve considerable attention. We cannot afford to waste the talents of these individuals. We must move more women and minorities into scientific and technical careers. We must also increase the abilities of women and minorities already in science and engineering to conduct reasearch, to serve as full participants in the scientific and engineering communities and to compete on an equal footing in the research arena.

We are pleased to see NSF support for programs to move these groups into the mainstream of scientific endeavor and in this country. Programs such as Visiting Professorships for Women, Minority Research Initiation and Research Improvement in Minority Institutions are a good beginning, but only a beginning. Program efforts must be expanded and levels of support increased to more appropriately address the magnitude of the problem of underutilization.

The effect of the dismantling of pre-college and college level programs is devastating to the aspirations of those who seek access to careers in science and engineering--women, minorities and the physically handicapped. This is the majority of the talent for the future --our hope for building the technical workforce for the future which we so desperately need to revitalize our economy, to ensure our national security and to increase our productivity.

Engineering Research: The engineering component of the NSF budget has not risen above 10 percent. Also, less than 10 percent of NSF's equipment and instrumentation funds go to engineering. Given the critical nature of graduate engineering in this country, it would appear that greater focus must be placed on the balance between engineering research and education and other fields.

Social and Behavioral Sciences: As you know, the initially drastic budget reductions in the social and behavioral science programs at the National Science Foundation were modified late last year by the administration and the Congress. But the strategy for FY 1983 seems to be to hold funding for these programs at the FY 1982 levels. However, it is worth noting that these support levels are still in the range of 40-50% of their FY 1980 amounts.

It bears emphasis here that many of the nation's problems dealing with energy, the environment, health care delivery, productivity and economic development call for continued research in the social and behavioral sciences as well as research in engineering and the physical sciences. Equally important, they call for cooperative and collaborative research among social, natural, and engineering scientists and demand a strong research base in all of these areas. Neglecting--or handicapping--entire fields of science will have serious negative impacts on our ability to meet the challenges of many of our most pressing problems.

Graduate Student Fellowships: Earlier I mentioned the problem of guaranteed student loans for graduate students. There is another troubling feature of graduate student education in science and technology: the erosion of fellowships and relatively low stipends for NSF fellowships.

While it is a favorable move to increase NSF fellowship stipends from $4,500 per year to $6,900--with $4,000 to the institution involved --this is a very tight amount. As an example of changes which more accurately reflect market forces, the Defense Department fellowships allow $12,000 stipends and $8,000 for the university. We would hope that in the not-too-distant future the NSF will be able to raise its fellowship support to the more realistic defense levels. Unless such comparability is provided, it is not too difficult to forecast that Defense fellowships will become more competitive than NSF fellowships--thereby impairing the quality of this highly important endeavor.

Conclusion and Recommendations

Let me thank you, Mr. Chairman, and other members of the Committee for this opportunity to be with you today. It is reassuring that those of you in the Congress continue to display deep understanding of the vital connection between scientific and technological advances with the well-being of the people of this country and our neighbors on this planet.

Finally, let me summarize several general recommendations:

(1) In the overall R&D picture, we have probably tilted too far in the direction of military R&D as part of our defense buildup; this seems to have been done at the expense of a number of civil sector areas, including certain areas within the NSF. Some redressing of this balance is suggested.

(2) Appropriate recognition of the role of R&D in economic growth and incentives for greater private investment need to be considered as part of our economic planning.

(3) Greater national focus--public and private--must be placed on longer-range perspectives vis-a-vis current short-term outlooks.

(4) A new national commitment and expression of national leadership are needed for solving major problems in science and engineering education.

(5) As a related point, we would hope that graduate students will not be eliminated from participation in guaranteed student loan programs.

(6) While staying close to the President's NSF request for FY 1983, I would suggest a few realignments and a modest increase to cope with the problem areas which I outlined for you.

Again, thank you for inviting us.

Senator HAWKINS. Thank you. It is my great pleasure to join you at such short notice. I have another hearing, as most Senators do, that I am involved with but came to relieve Senator Hatch, my good friend and colleague.

Dr. Burbidge, your testimony is very complete and we appreciate all of your presence here today. I would like to ask you or Dr. Parry, have there been any efforts made to involve the private sector in the university science programs in your State?

Dr. BURBIDGE. Yes. Shall I address this first?

Dr. PARRY. Go ahead.

Dr. BURBIDGE. Yes, indeed. In the private sector there are some major initiatives going on, and I know those in my own university, the University of California, to bring the local industries into cooperative programs. I know that NSF and NASA, which I am also familiar with, do have programs that are specifically targeted for cooperative efforts between industry and university research. These are just at their beginning now, I think, but I believe it is going to be a very productive way of going. Of course, it is not going to address the large-scale instrumentation problems that we have been talking about but it will be very positive.

Senator HAWKINS. Dr. Parry, could you give us your experience?

Dr. PARRY. Thank you. There has been an effort, an organized effort on the part of some segments of the chemical industrial community to get involved in the funding of university research. Their efforts have generated a modest amount of money but in actual percentage of the total needed, it is a very, very small part. I think we would have to conclude from the data that we have been seeing so far that this is not going to be any adequate substitute, or even make a serious dent in the problem of supporting basic research. I think that is now and will remain a Federal responsibility because it is too far away from the area of short-term payoff which Dr. Burbidge has already alluded to.

Senator HAWKINS. Are there any other members of the panel who would like to comment on that? Dr. Berlowitz.

Dr. BERLOWITZ. Senator Hawkins, I think that even in allowing industry to do business with the universities, there has to be a stable base of funding, a stable base of resources and facilities and instrumentation which permits this to happen. The only source of these in the past, and I think in the future, is going to be Federal funding.

Senator HAWKINS. Federal funding?

Dr. BERLOWITZ. Yes.

Senator HAWKINS. I think that unless some of you panel members have some experience that proves otherwise, that there is a great new thought out there in the private sector that in order to—not "catch up," I hate to use that word—that in order to compete on an equal footing with the Japanese, for instance, who have the advantage of the MITI board which conducts the first examination into which firm will do the research, and because of antitrust laws in the United States, we are reliant on NSF sponsored R&D. I happen to have personal knowledge that there are a lot of large corporations that feel in order to do the amount of R&D that is necessary today on one specific item—and we can take an electronics item, for instance—that the proper path may be through the

National Science Foundation. Manufacturers will benefit from the NSF funded R&D as a method to get around the antitrust restrictions. The National Science Foundation came up about 20 times in that conversation that evening, that that is the perfect vehicle.

Since funding has been cut—which was my contribution to the conversation in light of the approaching funding cuts—what would that do? The representatives there from industry, the private sector, were more than willing to say, "We will put in that money on a permanent basis. That is a great place to put it."

I think that is a new area. In days like today, when we are looking for new solutions to the old problems, I think that is an area that we must look toward.

Dr. Berlowitz.

Dr. **Berlowitz**. Senator Hawkins, yes, I agree with you entirely but I would like to make two points about that. One, the National Science Foundation and other Federal agencies have been tremendously successful in the past in leveraging Federal dollars by supporting cooperative research programs between universities and industry. We have a long history that we could go into.

The other point is that it is true that in an industry, a high-technology industry like microelectronics and the new, growing molecular bar technology industry in this country, that very close cooperation between the university and industry is taking place and industry is taking a strong interest in providing funding. However, there are many, many areas of research that are really important to the national endeavor in the long haul that are not going to be funded this way because they are not really related to the short-term interests of industry.

Senator **Hawkins**. Commercial interests.

Yes?

Dr. **Partridge**. That is one point that I think some people do not understand, and that is the difference between university research and industrial research. University research ordinarily is basic research, where the faculty member follows his own research program and uses that to train graduate students. He takes his time and follows the research where it takes him.

Industrial research is usually a team effort aimed at solving a particular problem. It is multidisciplinary and it has a tight time schedule. There is no question but many of the industrial people do need the expertise that is on the campuses; the campuses need the money that the industrial organizations are willing to put into their type of "research," but there is where we get into problems, when we try to match those needs and that expertise that is on the campus. It can be done but there needs to be an understanding of that interface, which sometimes is very complicated.

Senator **Hawkins**. The pace is what you are talking about.

Dr. **Partridge**. Right.

Senator **Hawkins**. Many would say that the single biggest problem today is instrumentation on the universities. Dr. Berlowitz, you have been recognized as an expert on the matter of university instrumentation. How far behind the state of the art is the average university laboratory, in your opinion? Are they far behind?

Dr. **Berlowitz**. Yes, they are. I believe that the National Science Foundation is gathering some recent data on this subject which suggests that the average is about 7 years behind their industrial counterparts in the obsolescence of instrumentation for research, on the average.

Senator **Hawkins**. Do you have any figures that would compare the United States with other countries?

Dr. **Berlowitz**. I do not have any concrete figures but in traveling around the country and talking to many individuals, there certainly is—especially in certain fields—there is an almost overwhelming feeling that we are losing out, that we are far behind.

Senator **Hawkins**. Dr. Parry.

Dr. **Parry**. Senator Hawkins, I think it is quite clear that we are behind but I think the problem has not been really put into focus in a quantitative sense as yet. There are a number of studies, including one by the American Chemical Society and several other organizations, trying to quantify this, trying to put numbers on it as to just what is needed. I think that it is very clear that the problem is real and that we are way behind. I think that the absolute numbers involved we still are a little uncertain on.

Senator **Hawkins**. Are there any disciplines which suffer disproportionately from a lack of modern, reliable equipment?

Dr. **Berlowitz**. I think that chemistry is one discipline that does, certainly, because chemistry is a discipline that is rapidly growing. The instrumentation over the past several years has become increasingly more sophisticated, and it therefore becomes increasingly more difficult for the university research scientist to keep up with new advances.

Another area, of course, is high-energy physics but that is really probably not part of this study.

Senator **Hawkins**. Are there any specific areas of scientific inquiry you feel have special promise over the next few years, such that special funding or organizational emphasis by the Foundation would be desirable? Any comments on that?

Dr. **Burbidge**. Well, yes.

Senator **Hawkins**. I know you hate to pick favorites, but——

Dr. **Burbidge**. Of course, the fields I know most about are those that I am particularly concerned with but there are various fields in biology, genetic engineering, new computer technology, the development of advanced detectors. The whole problem of data management, this is becoming an increasing problem with the flow of data and the archiving of data in an accessible way. This is something that really has to be addressed.

To get to special, sort of exciting issues in science, I think the frontiers, the places where different disciplines have interfaces, like chemistry with astrophysics, the existence of complicated molecules and the analysis of these in the space between the stars and understanding what the impact here may be in getting an inkling on the origin of life; the whole problem of managing the resources of our planet and eventually considering moving out into space; these are particular fields where I think there are breakthroughs coming.

The interface between high-energy physics and astrophysics, which is my own field, in looking back to problems that the general public seems to be very interested in when one gives popular talks, those are the question of the origin of the universe and the early history of the universe. These are exciting, forefront fields where big instrumentation is needed but more communication is needed and commuters, advanced computer technology and data handling.

Senator HAWKINS. I will have to agree with you on data handling. We are conducting a hearing today on the Farmers Home Administration, and I do not want to bore you with the problems that that agency is encumbered with right now because of the lack of being able to analyze the data that is in that Department. I mean, the old saying, "garbage in, garbage out" is still pertinent even after several generations of updating of their equipment in that tremendous agency.

Dr. Juster.

Dr. JUSTER. Senator Hawkins, let me add a couple of areas that I think are in a way more pragmatic but I think have enormous potential and enormous potential payoffs.

Senator HAWKINS. Could you speak up? I can't hear you, sir.

Dr. JUSTER. I am sorry. Let me add a couple of areas on the social, behavioral side. These are areas where I think there is enormous promise, where we know quite a lot and we know what needs to be done but one needs resources to do it. There are a lot of them but let me just focus on two.

I think there is an interface between medicine and biology and behavior which has a lot to do with health, where we now begin to understand that the solution to health problems is not necessarily better medical technology because a lot of our health problems are due to perverse human behavior: Smoking habits, seat belt wearing habits, diet, a whole range of rather mundane things which, as far as I can tell from what we know, have more impact on health status than enhancing the level of treatment for pathologies once they develop, so there is a lot more payoff in trying to prevent those pathologies than there may be in trying to find ways to fix them once they are there.

Now that is an interface between the biological medical sciences and the behavioral sciences, and I think it is the right field for a major exploitation but the resources need to be there to do it. Another one that is very different, we spend a lot of time these days worrying about how to expand our national savings rate. The President's program is designed to try to impact the savings rate. The fact of the matter is, if you ask how much do we know with assurance about what drives people's personal savings behavior, the answer is, we know a fair amount and there is a fair amount of disagreement. If you ask what is the net effect of what people think in terms of savings behavior, you would find most people saying it is very hard to make an impact on it and it is unlikely to be impacted by the kind of proposals that have been made but we are not sure of that.

The one thing that I think I do know about that is that we could solve the problem—"solve" in quotes because one never guarantees solutions—one could solve the problem by putting enough resources to generate a longitudinal data base on what it is that people actually save, to enable all the theories which now compete to compete against each other with a data base where they could resolve those issues. We do not have that data base; we have not had it for several decades. It is narrowly defined, nice problem which I think could be solved by putting additional resources and it would teach us a lot about what drives human behavior as well because savings behavior is, along with a lot of other things, one of the more fascinating intellectual kinds of processes in certainly economics.

There are four of five others but I will not take your time, but that is——

Senator HAWKINS. That is interesting. You could submit them by writing if you would like. The record will be open, and we would like you to submit that for our study.

Dr. JUSTER. They are noted in the statement I have submitted for the record.

Senator HAWKINS. I will tell you that I would be glad to supply you with the chart I had made that shows that the higher the person's savings per capita, internationally, by nation, has a direct correlation to the amount of tax paid on that savings. The Japanese can save up to $40,000—it is over $40,000 now—per person without being taxed at all, and it has a direct line. You can see that that it would be a big factor in this study that you are conducting.

Dr. JUSTER. I think that is right, and I think that there may well be those kinds of——

Senator HAWKINS. Dr. Laffler has a lot of——

Dr. JUSTER. Yes; well, he and I would not agree.

However, let me just give you one interesting fact on savings behavior which most people do not realize. and which bears on what the data mean. The Japanese save at a very high rate. We all know that. It is about 22 percent. Most people think the Americans only save about 6 percent, and we say there is a big difference: The Japanese are great savers and the Americans are not.

The fact of the matter is the Americans save about 18 percent of their income if you measure it the same way the Japanese do. The difference is, we "dissave" a lot. We incur a lot of debt and the Japanese do not. Therefore, in terms of saving the way you think about it, adding to savings accounts and putting into securities and whatnot, we are not very different than the Japanese. The big difference is, we buy houses and cars and durables and go on vacations and incur debt, and they do not.

Senator HAWKINS. They are frugal.

Dr. JUSTER. Therefore, if you could impact the debt side you would make a lot of progress on that, but we can argue about that at some later date.

Senator HAWKINS. Well, it is an ongoing argument, I am very interested in that. I have been to Japan twice as a member of the American Productivity Council, and will go again next month. It is very interesting to compare where we are and where we are going because it is, as you say, attitudinal behavior and a lot of incentives, stated and unstated, that you can unearth by visiting with their officials.

I had a question for Dr. Partridge: Your statement that the Government currently pays two to three times what would be required if intererst on outright purchases of equipment were reimbursed, implies that the costs to the Government to cover the interest costs would be less than rental or lease costs.

Dr. PARTRIDGE. I think the best way to answer that, Senator, is to give you an example of a project that we have where the principal investigator needed transportation, so under the project they were allowed to obtain a truck, a pickup truck. Because of the fact that interest is not allowable on equipment acquisitions, they could not enter into a lease-purchase which would have been the cheapest way to acquire that truck. It was a long-term project.

The auditors came in and questioned why they had just rented the truck and paid the interest rate and paid the high rate for using that truck over the years, and this was the only way they could be reimbursed under Federal regulations.

Several universities are taking advantage of the possibility of leasing equipment and then charging the lease costs to individual projects that use it, and they are having problems with the auditors because of Federal procurement regulations which will not allow interest to be reimbursed on a lease-purchase of equipment, but they will on an operating lease or a rental agreement. This is why there are times when the Federal Government is paying much more for the access to equipment on projects than they would have to if the contractor could enter into lease purchases and be able to be paid for the interest that is paid on that type of an agreement, or borrow money and be able to reimbursed for the interest on the money that they borrowed to make that purchase.

Senator HAWKINS. Dr. Parry, Dr. Burbidge noted in her testimony the efforts of the administration and the scientific community to come to some understanding regarding the export of scientific information through exchanges, meetings, journals, et cetera. What is your assessment of the success of the U.S. participation on the whole in such international exchanges? Do we get out what we put in?

Dr. PARRY. I believe the answer is a qualified yes. Like any aspect of human endeavor, we do not win on all of them but I think that there are a number of areas where, if we were to stop, we would have extremely serious problems. For example, the Foundation has supported the international unions and these international unions carry out an extremely important function for the United States in terms of defining nomenclature. This is of great importance in terms of commerce. They carry out the function of recognizing international problems which go beyond local boundaries. The support of these unions is, I think, an extremely important aspect.

Another thing is providing a way for scientists to travel and to mix with other scientists. Unfortunately, there is some feeling in some quarters that this is a bit of a boondoggle, but I could tell you a story—which I will not, for the time today—about Prof. Alan MacDyerment in a trip to Japan which had as its ultimate outcome the development of polyacetylene types of patterns, these very lightweight patterns. I think that this is an area where classically we are getting out in a few cases very large returns. One can criticize that some of these things may not always be just exactly what you would like, but I know of no area of human endeavor where you win on everything. They could not stay in business in Las Vegas if that were true.

Senator **Hawkins**. From you standpoint as research scientists and university professors, how do you feel the proportion of foreign students enrolled in American science programs will affect our country's economy and scientific progress in the long run?

Dr. **Parry**. Are you asking me?

Senator **Hawkins**. Yes; I went to school in Utah, and at the time I was in school we had more foreign students than we had Utah students.

Dr. **Parry**. The problem is that we would prefer to have American students doing the research. We would prefer to have them being trained to meet the technical problems which are arising, but because of problems which we had earlier in the system, and because of a general public disaffectation with science, we have not really had that group of people to do the work.

As a result, the university community has resorted to using more and more foreign students. Good research is being done. There is a payoff on this, and there is also the payoff that these people are then able to return to their lands and not only take back technology but I think they take back feelings about the United States and ideas which in the long run are helpful to us.

However, we do recognize as one of the problems that with a large percentage, something like 22 percent of the post-docs in the country being of foreign nationality, that the United States may suffer in terms of not having enough of our own people to maintain the scientific enterprise as it should be maintained.

Senator **Hawkins**. There was a great outcry in my State last year when there was an effort to limit foreign students. The community wanted that done, the citizens wanted that done, the taxpayers wanted it done. The administrators did not want it at all because they are paid *x* amount per student, and it is a fixed amount they can plan on long term. They did not have to wait until the next quarter to see what the enrollment would be. They have those projections already. I wonder how you——

Dr. **Parry**. I would be very uneasy with the idea of limiting the number of students by law or by any restriction until we had made a vigorous effort to try to bring in our own people in a constructive way. I think that would be self-defeating. I think, in the long haul, international interaction is all to the good.

Senator **Hawkins**. You made the statement that a lot of the benefit is when these people, students, go back to their country. Do you have any figures on how many do not go back, how many stay?

Dr. **Burbidge**. I would like to comment rather briefly on that. We have now a number of students from China, and a commitment for their coming is that they go back to their country.

Senator **Hawkins**. Is that something new, a new arrangement?

Dr. **Burbidge**. In terms of these students, yes, it is new because of the almost total decline of science in China during the cultural revolution. There are some scholars coming as well but they are mainly older people who have suffered from the effects of that terrible hiatus but the students that we see are really very smart and obviously highly selected from their own country. However, I regret to say they are consistently doing better in examinations and in their course work. However, they are committed to go back to their country.

I think this general acceptance of the best students from the international field does build international cooperation. It builds international good will. They go back. Some will stay. Some will indeed become U.S. citizens, and that is an enriching process too.

Senator **HAWKINS**. Some go back and lead the junta. [Laughter.] I am amazed how many have had American educations, which they feel are superior.

What is your reaction to the National Science Board's proposal for a Commission on Precollege Science Education? I am intrigued with that and I wonder if any of you have comments on that?

Dr. **BURBIDGE**. Well, the setting up of a commission I think is a good idea. Like other speakers, during Dr. Rutherford's testimony, I hope this is not just a holding action to avoid doing something right here and now. A commission to really focus on the problems, well, as has been said several times this morning, we do know the problems but a gathering of it all together and action by the NSF in a leadership role of directing the effort needed to address the problems, I think is good. Therefore, the commission can do good. It had better do its job.

Senator **HAWKINS**. Any other comments? Dr. Partridge?

Dr. **PARTRIDGE**. I personally am in favor of it. I think that the program that the Foundation had before was somewhat fragmented. If they can take the time to do a good study of what really is needed and formulate a program that has a good, solid base, I think that the foundation of science education in the country can be strengthened. Therefore, I am happy to see them do it.

Senator **HAWKINS**. Isn't that really part of the reason that there has been a dropoff in advanced science education, is because there was so little interest in it in precollege?

Dr. **PARTRIDGE**. Yes.

Senator **HAWKINS**. On my last trip to Japan, I spent a great deal of time looking into their education system. Their elementary and secondary program is phenomenal, and that was one of the reasons they are able to upgrade people from the line, the assembly line, so-called boring jobs, because they had such tremendous education and training that when they removed them from the assembly lines—boring work, they called it—they were able to upgrade them to the second and third floor and make engineers out of them while the robots took over on the first floor. Now you just cannot do that to the average line man in the United States, and I think it is something that we now are seeing that must be addressed in precollege, yes, maybe even high school. The National Science Foundation, I think, has a great responsibility for focusing attention on the plight that we are in today.

Dr. Juster.

Dr. **JUSTER**. I was interested in the discussion this morning on that, and I guess one of the clear impressions I had—I know very little about that subject—one clear impression I had is that a major part of the science education problem is not necessarily what it is that one should do under ideal conditions but how it is that you persuade a whole bunch of units with local responsibility to act in a way which capitalizes on what we all know. That is not an uncommon problem, and again it is a social science kind of problem. The issue is not, do we have the knowledge base to decide how one should go and train youngsters and interest them in science and engineering and technology? People would say, yes, we do know how to do that. The question is, how do you get 33,000 school districts, or 85,000, or whatever it is, to somehow or other act on that? That itself is a dissemination and diffusion problem. It is not clear to me where it is best located but it sounded to me as if that is the core of the problem, as opposed to if we could get people to do what we know we should do, how you would do it.

I think that knowing what we do seems to be better understood than how do you implement something where you think you know what the procedures are but you have all of this diffuse, local responsibility—as you should—and you have to get all of those people somehow to make decisions on the basis of some set of knowledge which most of them presumably do not have, do not have access to, and do not know quite what to do with it. It sounds like a dissemination problem, not a how-do-you-do-it problem.

Senator **Hawkins**. Our State is very short of engineers. I know that nationally that is another problem also but especially in a State like Florida that deals in technology more than hard goods, not a manufacturing State at all. The Governor just appointed a committee to look into that problem and what would be the solution. Of course, it is so simple: The solutions are to educate more engineers in the local schools.

However, so many citizens are upset and write to us: Why were we caught short? Why weren't the projections made? Why wasn't this data collected? Why didn't we know ahead of time that our son should have been studying engineering instead of sociology? We have paid all this money, and education is getting more and more expensive.

A man next to me on the plane this morning said that his son was very, very lucky: He had just graduated from college and had a job. He was just absolutely thrilled to death that he had managed to merge the two interests, in getting him off his payroll onto someone else's. It was only because of the choice that the boy took himself, he said, without any guidance at all after he had been in college 3 years. He managed to cram 4 years into 5 like a lot of our students do, his son, in order to get the proper major.

However, I would say that even if you had the data and you knew what was happening in the future, we are caught by surprise sometimes. Would you not agree, Doctor? For example, I did not expect the Falkland Islands to happen last week, and there are some issues over which we have no control which redirect the national interest and sometimes the international attention.

Dr. Parry, do you have a comment?

Dr. **Parry**. Yes. Dr. Slaughter blew my cover this morning as a member of this Commission. The Commission has not as yet met nor taken any positions. I guess my own feeling is that we know that some things have been very good in the past but we also know that using many of these same activities, we have gradually dropped down to the current sad condition which we see in science education in the world today or in the country today.

I think that, without trying to place blame or anything else, it is important that we take a look and try to decide what goes on and what can be done with limited resources.

Senator **Hawkins**. I appreciate your staying and your attendance here today. I am being summoned back to my own hearing and would like to submit the rest of these questions for the record, if you do not mind. You could answer them by correspondence.

We will conclude this hearing at this time. Thank you so much for your participation.

Dr. **Burbidge**. Senator, thank you very much for inviting us and for listening to us.

[The prepared statements of Dr. Berlowitz, Dr. Partridge, Dr. Juster; and additional material supplied for the record follow:]

Testimony before the
Senate Committee on Labor and Human Resources
on the Fiscal Year 1983
Authorization Legislation for the
National Science Foundation

by

Dr. Laurence Berlowitz
Provost, Clark University

Statement of Laurence Berlowitz, Provost of Clark University to the Senate Committee on Labor and Human Resources

Mr. Chairman,

I am Laurence Berlowitz, Provost of Clark University. Thank you for inviting me before the committee to express my personal views on the instrumentation and facilities needs of research universities. My appearance has been coordinated by the Association of American Universities, and many of the views that I shall express are derived from and are consistent with the nationwide AAU study * that I and my colleagues did for the National Science Foundation in June of 1980.

More recently I have headed a panel of the American Association of the Advancement of Science on instrumentation obsolescence. The resultant report was a contribution to the Fourth Annual Science and Technology Report of the Office of Science and Technology Policy. I have also recently been involved with a massive and comprehensive study of current university-industry research relationships that will inform this year's National Science Board report, and which gave me further opportunity to explore the instrumentation problem.

The growing obsolescence of research instrumentation in the nation's universities is a problem not just for the universities, but for the nation as a whole. To the extent that such obsolescence impedes the progress of fundamental research at the university its effects will be felt in such areas of application as agriculture, medicine, biotechnology, engineering, energy, industrial productivity and national defense. Since over half of U.S.

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* - The Scientific Instrumentation Needs of Research Universities. A report to the National Science Foundation by the Association of American Universities; June, 1980.

- L. Berlowitz, R.A. Zdanis, L.C. Crowley, J.C. Vaughn. "Instrumentation Needs of Research Universities," Science, Vol. 211 (6 March 1981), p. 1017.

basic research is carried out at our universities, a decline in the research potential of the universities will result in a significant decline in the general rate of scientific advancement.

While scientists with analytical and synthesizing minds make the great discoveries, instrumentation is at the heart of experimental research. It provides the tools that are necessary to make those discoveries. Without modern state-of-the-art instrumentation it is impossible for scientists to engage in frontier research. Instrumentation opens up whole new fields of scientific inquiry and can greatly reduce the time necessary to carry out research projects. It is currently a great concern among leaders of the scientific community that instrumentation in the cost range of $100,000 to $1,000,000 is rapidly becoming obsolete at United States research universities. As a result of rising costs and the drying up of sources of local funds it cannot be easily replaced with current state-of-the-art equipment.

The cost of instrumentation has increased well above the inflationary baseline primarily due to the increasing sophistication of the instruments required for frontier research. The costs of operation and maintenance also continue to rise precipitously. While costs rise, funds for instrumentation and its support have dwindled at both the local and federal levels. It is rather gratifying to see that the FY '83 National Science Foundation budget has been responsive to this dwindling resource and has earmarked 11.5 percent more specifically for major equipment above the FY 1982 current plan. But the problem is far from solved.

I have been an administrator at a large urban research university, New York University, and now at a small university in New England, Clark

University. Although small, Clark has always excelled in certain areas by specializing and fostering resources. I have seen from two very different points of view the effect of lack of instrumentation on the ability to do frontier research. Clark's Chemistry Department faculty know that a multitude of instruments is not affordable within its budget. Alternatively, they are focussing their resources on a single type of instrument, the Nuclear Magnetic Resonance (NMR) spectrometer. Much of their research stems from using this instrument in a variety of ways. In the 1970's the development of NMR opened new areas of research in the structural sciences by allowing scientists to define the structure of matter with a resolution never before achieved. The cost of such instrumentation has gone up enormously and so has its sophistication. Clark has recently been awarded an extremely sophisticated machine by the National Science Foundation with the strategy that it become a regional center for NMR. A consortium of universities has joined forces to use this center. One of the major problems related to the facility is the difficulty in having continual funds for operation and maintenance of such an instrument once it is awarded. Although Clark was able to match the National Science Foundation's original grant (the cost of the latest instrument is a quarter of a million dollars), the university is hard-pressed to provide maintenance, operation, and training costs even with user charges. There is general agreement among laboratory managers that the additional cost of equipment ownership runs about 7-8 percent of the new cost per year. That includes maintenance, replacement parts, staff salary and equipment expenses. But generally funds awarded in federal grants do not contain provisions for such maintenance and maintenance funding at universities has become extremely scarce. The operating budget for Clark's Chemistry Department is small. This year we could not increase it significantly because we opted to put more money into student aid to offset student loan cuts and help retain our classes. Our shops have deteriorated, as many shops across the country have, and costs of service contracts have risen well above the inflationary baseline. Because of this, our top level scientists who should be spending their time doing their science have to spend considerable time just maintaining and operating instruments.

Another problem is inadequate facilities to house instruments. The term "deferred maintenance" has become a commonplace word in the academic world. (At a world renowned physics department that I visited recently, the facilities were so deteriorated that water filters had to be changed several times a day just to get it pure enough to put through the deionizer.) Clark is now in a capital campaign to raise money to improve its science facilities so that it can adequately house such research instrumentation. Because of the federal cut-backs and threat of even more federal cut-backs, the competition for private funding becomes stiffer all the time.

Mr. Chairman, Clark is no exception to the rule. Even at a large, private university like New York University, where I had the pleasure of administering a research challenge fund to encourage investigators to provide seed money for young people who could go out and get their own grants and to generally improve research, the amount of money I had per year would hardly fund a single sophisticated NMR. Furthermore, adding to the problem, departmental operating budgets at NYU are being cutback, rather than increased.

Mr. Chairman, university researchers working with state-of-the-art instrumentation have always played important roles in the development of new scientific instrumentation that ultimately results in superior industrial products and has enabled this country to retain a competitive edge. A recent study of 111 improvements of basic scientific instruments used in chemical and biological research reported that of the 44 innovations which were later incorporated successfully into commercial products, 81 percent had been initiated by instrument users rather than instrument manufacturers. Of those users, 72 percent were employed by universities or affiliated research institutions. New instrument development will be impeded when universities cannot afford to purchase state-of-the-art equipment and ultimately the whole economy is the loser. On a recent visit to one of our major national research universities, I talked to a person who had played a significant role in the development of a particular electron microscope, and who could not now go out and afford to buy the best model of that microscope which he himself developed.

Universities have also played a major role in the industrial innovation cycle for instrumentation. Firms that have spun off from university departments have produced some of the more advanced important instrumentation, for example the CAT scanner, a major diagnostic medical tool. If universities drop out of the innovation cycle, one means of getting innovation rapidly to the marketplace may be lost.

Mr. Chairman, where will help come from to alleviate the instrumentation problem? Many are looking towards corporate funding or research instrumentation, and I am sure that some of that will be forthcoming and that such funding will be useful but it will only be available for a limited number of research areas -- those that are most directly related to industrial needs in engineering and high technology. Science that is in the long-term strategic interest of the country, but not directly in line with immediate industrial need, will not be supported by industry in significant amounts. Recently I visited some of our major corporations in central Massachusetts to ask them to help contribute instrumentation to the universities. Their general response was that they would be glad to contribute -- but only surplus equipment, some of which is useful but much of which is obsolete. Many of these corporations do not have fluid capital, are not ready to make investments even when they get tax credits. These corporations may be able to make an initial investment but then they will not plow the credits back into further continuing investments in university research. A tax credit is clearly one step in the right direction, but the magnitude of that step has not yet been determined. In a New York Times article of last year, the late Arthur Bueche, senior vice president for corporate technology at the General Electric Company, is quoted as saying "the legislation biases the system in the right way, but I don't expect it to have a major stimulative effect." The severity of the current recession certainly determines the extent to which tax credits and similar provisions will be put into effect.

This last conclusion underlines an important aspect of the university/industry relationship with regard to the funding of research: Corporate behavior is necessarily influenced by economic fluctuations. Corporate allotments for research usually fluctuate accordingly, yet research efforts require consistent, reliable sources of funds, particularly for equipment and maintenance if productive research is to be accomplished.

The ability of industry to work cooperatively with universities depends entirely on a stable base of university resources, heretofore made possible primarily by Federal funding.

The ability of the federal government to leverage university/industry cooperation is provable and commendable. Our NMR facility at Clark University funded by NSF will be attractive to industry. Not only will industry provide Clark with some of the needed maintenance and operational funding, but the NMR facility will also encourage local industry in the area to learn to apply the sophisticated instrumentation.

After considering all kinds of innovative financing and industry support, the Federal government will still have to play a major direct role in mitigating the instrumentation obsolescence problem, as well as in providing incentives for corporate action.

A number of Federal possibilities may be explored. Special instrumentation funds established to meet the particular needs of instrument acquisition and maintenance can be expanded. Funding agencies can also provide assistance by allowing more flexibility in funding procedures for research grants.

A specific funding mechanism that would provide flexible funding at the local level would be a carefully designed institutional grant program specifically earmarked for equipment and the associated support services, and based on a proportion of total direct federal support received. Such a program would allow the diversity of needs associated with instrumentation to be best met at the local level, while maintaining full Federal accountability.

The establishment of more block-funded research centers, such as the materials research laboratories funded by the Department of Defense and the National Science Foundation, can also help to alleviate the obsolescence problem. A recent study showed that these centers are able to provide better instrumentation for their laboratories than equivalent project-funded laboratories. Universities that have these block-funded research centers have been very fortunate in their ability to develop new research areas.

Let me end on a personal note. In the mid-sixties, as a recent Ph.D. in genetics, I went off to a wonderful post-doctoral experience at the Institute for Animal Genetics in Edinburgh. I returned to this country full of excitement and expectations and took up my first professorial position in a large Eastern state university. That university offered me about $25,000 to furnish my laboratory with appropriate instrumentation and supplies. With that seed money, within six months I had set up a research laboratory at the frontier of my science. I successfully competed for a research grant from the NSF, and I was in business; $25,000 in sixties dollars along with supporting departmental equipment were adequate to permit me to thrive. Today, in that same university, the start-up sum has shrunk -- the institution would find it difficult to offer even half that sum in eighties dollars to a young investigator starting out, and the personal and departmental equipment necessary to do my science -- at the frontier -- costs conservatively eight times what it did in the sixties. This example is not unusual. In the field of synthetic organic chemistry, for instance, the differences between funds needed and those available for instrumentation would be even greater.

In conclusion, Federal agencies must continue to explore ways to provide balanced, consistent support through policies that will allow research universities to acquire and support the advanced instrumentation essential to basic research. The problem is real, and it should be corrected before it has a permanently deleterious effect on our national research effort.

STATEMENT BY DR. WILLIAM S. PARTRIDGE

Submitted to the Committee on Labor and Human Resources

With Reference to S2349
National Science Foundation Authorization for FY 1983
April 15, 1982

America's position in the international economy and in world politics is directly tied to our ability to consistently produce useful processes and products that achieve leadership in world markets. When we lose that leadership, we lose the favorable balance of trade supportive of a healthy economy and we lose the prestige and position of strength required for favorable negotiations in world politics.

The chain of progress leading to scientific and technological preeminence begins in basic research which generates new knowledge. Properly shared, new knowledge is utilized by industry to produce applications which affect American life in many ways: improved health, enhanced food and energy supplies, new materials, new machinery and equipment and new systems to protect and advance American goals.

New knowledge is not produced at random. There must be organized effort, stimulation, encouragement and support. This is the critical role filled so successfully by the National Science Foundation as it provides funding for research, and fellowships for training the next generation of our nation's researchers. Areas in which new work is needed are identified. Directions for future effort are clarified. Incentives are assured for keeping outstanding, productive individuals in basic research programs. NSF's central involvement throughout the entire field of basic research provides direction and planning for future needs.

The National Science Foundation is the effective focus and rallying point for science in the United States. Essentially, it is a mission agency whose mission is the health of science across the board. NSF's country-wide view of research in progress and first-hand acquaintance with the capabilities of organizations and individuals places the Foundation in a singularly favorable position to coordinate, integrate and evaluate our basic science effort.

The special insights developed by the Foundation management and staff can be of invaluable assistance to those who establish science policy and address the problems that science and the scientific community are facing.

There are many problems which seriously affect the nation's ability to maintain a strong scientific base which Congress and/or the agencies of the federal government could solve by modifying present policies. In many cases policy changes would increase the effectiveness of the basic research program in the country and save money at the same time. Congress and the policy makers should take advantage of the special insight available at the Foundation as they address such current problems as the five examples listed below:

1. Interest costs on the purchase of equipment used on government-sponsored research projects: Present procurement policies are costing the federal government money because the regulations specify that the payment of interest on the purchase or lease-purchase of equipment to be used on government contracts will not be reimbursed. The result is that government agencies are forced to reimburse contractors through less cost-effective operating leases or equipment rental agreements. Thus, the government pays up to two or three times what would have been required if regulations allowed the contractor to recover interest on a lease-purchase or on money borrowed for an outright purchase.

OMB is considering a modification of Circular A-21 which would allow the reimbursement of interest costs on some equipment purchases. I am hoping that the final version will correct the problem described above.

2. The need for an effective science education program and for fellowships in critical areas: The National Science Board has established a special commission to study pre-college education in science, mathematics and technology and to help generate a national agenda for science education. I hope that the results of this study will indicate the direction which

should be taken by a new science education program. One major requirement of such a program should be to help train effective science teachers and to provide fellowships for graduate students in fields where additional scientific personnel will be needed in the future. Furthermore, the fellowship stipends must be increased to a level attractive to individuals with baccalaureate degrees who find job offers from industry more appealing than the high cost of continuing graduate education.

3. Indirect costs: Universities and other organizations currently carrying out research are wrestling with the increasing inflated costs of keeping their doors open. As a result, the indirect costs associated with doing research are also increasing. This has caused concern in Congress as well as on the campus, but indirect costs are real costs and must be reimbursed by funds from some source, whether it be by the federal or state government, by private contributions or by student tuition and fees. A sizable amount of the indirect costs being paid by universities doing federally sponsored research is the result of conforming to federally mandated requirements. Many of these requirements have little to do with accountability for federal funds. The ultimate determination of accountability for federal funds on a research project should be whether the work done under the project was in accordance with the awarding document and of the quality required, not whether every dollar was spent in accordance with a series of accounting principles.

An example of a specific policy change which could materially affect the ability of universities and non-profit research organizations to carry out federally sponsored research projects, is a proposal which has been submitted to Congress by a federal agency (not NSF), under which that agency would reimburse only 90% of allowable indirect costs on research grants. Such a policy could detrimentally affect the nation's science effort by denying support to investigators whose institutions cannot afford to provide this additional cost sharing on federal projects. Thus, the mix of science investigators could be changed with some qualified researchers being denied access to federal support. Specifically, this policy, if accepted, will prevent many non-profit research organizations from accepting research grants from that agency since they do not have retained earnings as a source of funds to cover the indirect costs for which they would not receive reimbursement.

4. Financial burden placed on universities and private organizations doing work for the government: In a recent study by the General Accounting Office of representative samples of invoices paid by the Federal government, it was found that 39% of the federal government's bills are paid late. This results in the federal government unfairly borrowing up to $11 billion per year from business firms by not paying its bills on time[1]. Furthermore, as mentioned earlier, the government will not reimburse a contractor for interest incurred when borrowing money to do business with the government. If an organization doing business with the government is required to pay interest on money used to perform under that contract or grant, the interest expense should be allowable under government procurement procedures.

5. Function of the national laboratories: Due to changing priorities, some of the national laboratories are experiencing budget cuts and thus are looking for additional sources of funds in order to maintain their staff and cover operating expenses. As a result, they are competing directly with universities and other research organizations for research funds available from federal agencies and also from the private sector. Many are soliciting support from other governmental agencies under interagency agreements because it is much easier to fund a project through this mechanism than it is to go out for a procurement under regular procurement regulations. Interagency agreements are many times justified on the assumption that it is cheaper to have another federal agency carry out a project than go to the private sector. This assumption is not justified when the full costs of running a government laboratory are included in project costs rather than only the out-of-pocket costs

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[1] "The Week in Review 81-41", Deloitte, Haskins and Sells, October 9, 1981.

experienced. A major disadvantage of having a research project done at a government laboratory rather than a university is evident when one considers that research projects at universities support the training of graduate students while those at the national laboratories very seldom perform this function. I personally believe that if a national laboratory performs research work that could have been done as effectively and as cheaply by a university or a private research organization, it is a case of misuse of government funds.

In summary, even under the present economic conditions, it is imperative that basic research be supported so that the knowledge required for technological development and the nation's security will be available when needed in the future. The National Science Foundation is concerned with the health of science in the United States and can provide valuable insight into problems and policies affecting science when they are addressed by Congress and governmental policy makers.

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Statement of Dr. F. Thomas Juster

Director, Institute for Social Research,
and Professor of Economics
The University of Michigan

Prepared for

Senate Committee on Labor and Human Resources
Orrin G. Hatch, Chairman

April 15, 1982

Mr. Chairman and Members of the Committee:

My name is F. Thomas Juster, and I am Director of the Institute for Social Research and Professor of Economics at The University of Michigan. By way of general background, I am an economist with an interest in the behavior of households and the measurement of well-being, and a Fellow of the American Statistical Association. At present I am a member of the Advisory Committee to the Congressional Budget Office, to the Consumer Advisory Council to the Federal Reserve Board, to the American Statistical Association's Advisory Committee to the Department of Energy, and am Chairman of the Executive Committee for the Conference on Research in Income and Wealth.

Summary

My statement relates to the research program of the National Science Foundation, and in particular to the Social, Economic and Behavioral Sciences part of the program. I would like to make four principal points.

First, investments in knowledge are fully as important for increasing our lagging productivity growth as investments in factory buildings, machines, or new technological applications.

Second, investments in knowledge about the functioning of society and the economy, which is what social scientists do, warrant fully as much priority and have fully as much payoff as investments in knowledge about engineering, physics, chemistry, biology, mathematics, geology, atmospheric sciences, etc.

Third, the present and recommended funding levels for the support of Social, Economic, and Behavioral science programs within the National Science Foundation represent a serious misallocation of scientific resources: While it is difficult to make judgments about how big the various scientific programs ought to be, the social sciences have been allocated substantially fewer resources than their quality or their potential contribution to society would warrant.

Fourth, a substantial number of important research activities that have already been proposed and approved cannot be undertaken within the FY 83 budget levels recommended for the Social, Economic, and Behavioral Sciences. Perhaps of even greater relevance, there is an extensive array of research topics of the highest priority that cannot even be contemplated within the recommended budget levels.

The Utility of Basic Research

One of the most important and perceptive generalizations about human behavior is that "knowledge is power." Everyone on the Committee has heard that before, and everyone probably agrees with it as a general statement. But it is important to understand that useful knowledge is a public good that cannot be produced without public support. It is not that brilliant ideas--genuinely new insights about physical or social phenomena--can automatically be generated by providing research funds to scholars, but that these insights do not become usable knowledge until they have been refined, elaborated, explored, and tested by people trained in scientific methods and enthusiastic about scientific inquiry.

How new ideas are generated is always something of a mystery. But how a fund of useful knowledge is produced is no mystery at all--it takes sustained investments in exploring the boundaries of the various scientific disciplines. Those investments feed on each other--the exploration of new ideas almost always raises more questions than it answers--and that iterative process is how scientific progress is made.

It is important to understand the nature of the payoffs to the new scientific knowledge generated by basic research programs.

We know that the practical payoffs are long-delayed in time and are highly uncertain with respect to specific projects. Research in both the natural and the social sciences is not dissimilar to drilling for oil--a large number of explorations are expected to yield one or two big gushers, a couple of moderate-size producers, and a good many dry holes. The exploration program as a whole is worthwhile if the yield from the producing wells repays the investment in the dry holes, in addition to their own investment costs. Since no one can predict in advance which idea will become a big gusher and which will be a dry hole, it is necessary to take risks--with the strong presumption that some projects will not (with the benefit of hindsight) have been worth undertaking.

The analogy between basic research and drilling for oil is not quite perfect. The biggest discrepancy is that scientific "dry holes" usually lead to some useful scientific consequence--as a minimum, we can put to rest a theory that turns out to be fatally flawed.

Finally, we know from studies in areas where the practical returns can be identified that most research ideas produce socially useful products with a considerable time lag and often in unpredictable ways. And we also know from such studies that the overall rate of return to investment in basic research is very high:

> A study of the return to private sector R&D estimated that the total societal rate of return is between 50 and 100 percent per year--a good deal higher than the return to private investment (generally 15-20 percent), and several times higher than the private rate of return to R&D (estimated at 25 percent). These results imply that the private sector will tend to underinvest in basic R&D if profitability is the sole guide, and suggest that the public sector is likely to underinvest in R&D relative to other forms of both public and private investments.
>
> In a study of the relation between government investment in R&D and economic productivity, the principal impact on productivity was indirect and appeared only with a significant lag of more than three years. Interestingly enough, government-sponsored R&D influenced productivity mainly through its impact on private sector R&D, rather than directly.

> A study in the biomedical sciences indicated that of a number of seminal ideas, more than half did not produce useful results until some 20 years after they had been discovered, and close to half had eventual application in areas that were unrelated to the original purpose of the study.

The Utility of Social Science Research

The landscape of social science concerns ranges from micro problems such as the way in which the human brain receives and processes external stimuli to macro problems such as the causes of conflicts between nations. Most social scientists worry about problems somewhere in between--they investigate the structure and stability of family relationships, or the dynamics of voting behavior, or the way in which schools and families participate in the process by which children learn, or the saving and spending behavior of consumers, etc. As a generalization with many exceptions, most social scientists are concerned with the attempts to achieve a richer understanding of how society and the economy actually work, with the ultimate objective of providing decision-makers with two types of insights--an accurate description of economic, social and political conditions in society, and a set of theories or generalizations which will enable the ultimate users of scientific findings to understand, and sometimes predict, societal change.

Although there is a considerable private sector return to basic social science research that takes the form of providing training for the skilled people that staff corporate strategic planning groups, financial planning groups, marketing groups and consulting firms, the principal returns to basic social science research are not directly on private sector performance. Rather, they consist of:

1. a framework of information and analytic relationships which help us to understand how our economy and society actually work;

2. a critical assessment of ideas about how to make the economy and society function better;

3. the substitution of fact and tested theory for myth and stereotype;

4. insights into the characteristics of important social and economic problems--inflation, productivity, crime, population change, etc.

It is important to note what is a reasonable expectation for the flow of potentially useful products from the social sciences, since it does just as much damage to overpromise results as to undervalue what products are actually feasible. Developing basic understanding of behavioral phenomena--how individuals respond to various external forces, and how the cumulation of individual decisions shape movements in the society and the economy, is a much more uncertain enterprise than trying to figure out the laws underpinning the natural universe, whether it be planetary motion, molecular structure, or genetic code. Thus social science research yields results that are probabilistic in nature, and which contain uncertainties about behavioral responses that are not only inevitable but are sometimes uncomfortably large. That situation may change as the social sciences build the kind of cumulative and tested knowledge base that all of us aspire to, but it is unlikely to change dramatically in the near future.

The Role of Information and Data

I believe that the Committee should pay special attention to the role of information and data in the social science research programs of the National Science Foundation. Supporting an adequate flow of relevant data about society and the economy yields a number of benefits:

1. Viewed simply as descriptive statistics, information about society and the economy provides an essential background for an informed discussion about policy or the consequences of policy changes: A solid information base serves as a benchmark from which changes can be measured and analyzed.

2. A carefully designed information base is an indispensable ingredient for the development and refinement of theoretical and conceptual structure.

3. Well-designed scientific data bases, especially those with longitudinal characteristics, offer the best prospect for achieving a base of tested and reproducible social science knowledge.

Let me provide a few simple illustrations of the role of relevant and reliable information in setting a framework for policy discussion and formulation. As suggested above, an important function of social science research is to help inform such discussion.

•It is widely believed that the U.S. voting public has become disenchanted with the political system and is therefore less inclined to vote.

•It is widely thought that the U.S. labor force, particularly blue collar workers, have become increasingly unenthusiastic about the work environment, and are therefore increasingly inclined to loaf on the job.

•Many people appear to believe that the U.S. welfare system has created a large underclass of families that are permanently dependent on welfare payments.

Our existing knowledge of behavior suggests that none of these perceptions is accurate:

> Voter turnout is not lower than several decades ago, and there is no discernible relationship between variations in turnout and measures of voter cynicism or disenchantment.
>
> There is no convincing evidence that worker dissatisfaction with the job is higher than in earlier decades, and a recent study of the "intrinsic rewards" from work suggests that people get more satisfaction from work than from most leisure activities.
>
> The proportion of U.S. households that are permanently dependent on welfare (in the sense that they received more than half of their income from welfare payments every year for a decade) is less than one percent, compared to the roughly 10 percent of U.S. households who received welfare payments during a recent typical year.

An important characteristic of the data-base programs at the NSF is that they provide a reusable resource. A well-designed scientific data base will turn out to have hundreds of both academic and public-policy users over its lifetime. It will be the source of applied scientific work by academic and policy users who want to estimate response parameters for various types of behavior, a source of testing and refining theory, and a source of generating new and richer theory. Thus the returns from the creation and maintenance of these information bases extend for a long period of time into the future.

It should be noted that the development of scientific data-bases requires substantial resources relative to the typical analytical project supported by the National Science Foundation. For example, one such project costs roughly $1.5 million annually, while another has costs that average slightly over $1 million annually; the typical NSF project in the social sciences runs from $50,000-$100,000 annually. In many ways, support of these data-bases is the social science counterpart of support in the natural sciences for national laboratory facilities (linear accelerators, observatories, electron microscopes, etc.). The latter costs a great deal more than the social science data-bases, but are properly viewed as indispensable to scientific progress. I suggest that the benefits from scientific data-bases in the social sciences are equally large, even though they are perhaps equally costly relative to the modest resources available to the social sciences.

The Budget Recommendations

The social science part of the National Science Foundation has tended to run at approximately five percent of the total--in 1980, for example, the Social, Economic and Behavioral science programs had roughly $50 million out of approximately a one billion dollar total. With that comparatively modest amount of resources, the behavioral and social science program attempted to accomplish four principal functions:

1. Support of basic theoretical work in the various disciplines;
2. support of methodological/statistical work related to the collection and analysis of data;
3. support of new initiatives, often risky ones, with the potential to extend the reach and power of the various disciplines;
4. support of large-scale measurement projects, including the continuing collection of scientific data with the potential to monitor societal change over time and to provide the basis for the testing and refinement of theory.

The Administration's recommendation last year was to cut the $50 million dollar budget at NSF to approximately $20 million--a cut that would have have destroyed the integrity of the program. As a consequence of the strong support for the Social, Economic and Behavioral Sciences shown in the House and Senate Appropriations Committees, the NSF restored some $11 million to these programs. This indication of Congressional support for social science research was received with great appreciation by the social science community, although we are also painfully aware of the fact that the current level of support is just about half, in real terms, what it was two years ago. Moreover, as one of my colleagues remarked in testimony before the House Subcommittee on Science, Research and Technology, we know that the glass is half empty rather than half full because we have just seen it being emptied.

The current budget recommendation essentially calls for continuation of the FY82 level, although the NSF as a whole was recommended for an approximately seven percent increase over FY82.

I do not think any defensible case can be made for the proposition that the social sciences have less utility to the society, or to the Congress and the Administration, than the natural science program within the NSF. They obviously produce a smaller total flow of useful products, since they receive a smaller amount of total resources. But the only study that seriously attempted to compare the quality of social and natural science research at the NSF came to the conclusion that, at the margin, the former was at least as high quality as the latter. Thus I urge this Committee to restore funding of the social science programs at the NSF to reasonable levels--say, those prevailing in 1980.

The case for such restoration of the NSF budget seems to me quite strong, both on scientific grounds and on grounds of prospective payoff. Whether that is accomplished by reprogramming of resources allocated to the various research and other activities, or by augmentation of the NSF budget to allow restoration of the social science programs to 1980 levels, is an issue that can reasonably be argued either way. My own view is that basic research and development is more important than usual even in the current constrained economic environment, and that augmenting basic research resources should represent a high priority for the Congress. But budget constraints are evident, and the Congress may not be able to justify adding resources to scientific research when severe program cuts are proposed in most other areas.

I would point out that even with restoration to 1980 levels, the social science programs would still have suffered an erosion in real terms of some 20-25 percent, a degree of constraint that seems to me about the same as that being proposed elsewhere.

What Would Be Accomplished By Increased Social Science Funding?

At the budget levels recommended by the Administration, a substantial set of research activities could not be supported. For example, a large set of programs concerned with the development of large-scale longitudinal data bases have already been approved by the scientific review process within the NSF, but the recommended budget provides resources for only two of them to operate at levels consistent with the collection of new data. The other programs will be in a "hold" pattern, pending the availability of resources.

As illustrations, the budget will not accommodate the collection of data on the General Social Survey (which documents trends in a wide variety of social conditions in the U.S. population), or on the time use of American households (which permits current analyses of the underground economy, of volunteer activity, and of changes in labor productivity based on reliable estimates of time spent at work), or expansion of the environmental data base, or collection of new data on the perceived quality of life among U.S. households. And even in such high priority- and event-bound data series as the Panel Study of Income Dynamics and the National Election Studies, only minimal rather than optimal data collection efforts can be sustained. In short, a set of programs with extremely high priorities from the point of view of understanding societal change and furthering the development of social science theory cannot be sustained within the recommended budget.

In the area of theory, methodology and new initiatives, the available resources require either rejection or sharp curtailment of a substantial amount of the highest quality proposed research. In my own institution, for example, a number of such proposals have been funded but at levels half or less those required to do the job effectively. Other proposals have been approved in principle as high priority, but rejected because of insufficient funding.

The impact on the Social Science programs of the present funding constraints varies considerably across the different programs. In some areas, program managers have opted to keep the same number of active projects but to cut the budgets in half, thus deferring decisions about which areas to eliminate. The hope is that the research activities would be reduced less than implied by the drastic cuts in project budgets--presumably universities and their faculties will one way or another absorb the difference. That may or may not be the outcome in the short run--but it will certainly not be the outcome in the long run.

Other programs have adopted a different strategy. In sociology, for example, major programs in Statistical Methods involving log-linear analysis, network analysis and risk analysis have already been sharply curtailed and can be expected to decline further, and studies of the way in which organizational processes influence worker mobility, job satisfactory and productivity are threatened with discontinuance.

Not only is it true that highly valued research activities of a continuing nature cannot be undertaken within the recommended budget, but that budget largely precludes a number of important new initiatives. Let me cite a number of research areas where there exist promising new initiatives with major public policy as well as scientific importance: these are gleaned from my own experience and that of a number of my colleagues. It is obvious that many more illustrations exist.

Saving Behavior

> We are presently concerned as a society about the adequacy of personal saving to support appropriate levels of capital formation. It is recognized that an increase in the rate of capital formation is essential to the improvement of productivity performance, and that the required capital formation depends on an adequate flow of private saving. But the fact of the matter is that we have little

tested and reliable knowledge about what determines private saving behavior, how saving might change in response to various tax or other stimuli, what will happen to saving as the population ages and as private pension coverage increases, etc.

One important reason for the uncertainty about our knowledge of saving behavior is the virtual total absence of an accurate set of data that measures personal saving, and its change over time, at the level of the individual household. The best such data were obtained almost two decades ago, while the most recent data (of dubious reliability) were obtained in the early 1970s. Neither of these studies has a longitudinal dimension.

It is possible to design a study that would fill this gap, but it would be very costly (perhaps $5-10 million) and would have to represent a long-term commitment over something like a five year period. Unless that gap in knowledge about behavior is filled, we will not know much more after the next decade than we know now, and the same unanswered questions will exist. But in the current environment, one could not justify the considerable effort needed even to prepare such a proposal, knowing full well that it cannot be afforded.

Productivity of the Firm

Despite all the attention paid to the recent decline in national productivity, our ability to understand productivity change at the level of individual firms is severely hampered by the information base. It is not that we lack data on firms that relate to productivity; but we do not have longitudinal data at the right level of aggregation (the individual firm, where investment decisions are actually made), and the available data are not really well-suited for productivity analysis since they were not designed for that purpose.

Creation of a productivity-oriented data base for individual firms will yield substantial benefits only if it is seen as a long-term effort: Analyzing changes in the investment and productivity of the same firms over extended periods of time is generally agreed to be the only effective way to address the problem.

Family Structure and Development

Impressive evidence has accumulated during the last decade that family configuration (family size, birth order, spacing of children, etc.) has systematic effects on intellectual development. There are good reasons for believing that the model developed to explain these effects might also be useful in explaining other aspects of development as well--socio-emotional development, the development of loyalty and role specialization in families, etc. To pursue this potentially rich harvest of theoretically and pragmatically important outcomes would be expensive--there would have to be a longitudinal survey reflecting an adequate national sample of the various types of family configurations.

Technology and Organizational Structure

A great deal of production-oriented behavior takes place in group settings. This is true for military activitiy, workplace activitiy, and educational activitiy, to name just three. Moreover, the nature of much of this group-oriented interaction is likely to be substantially changed in the near future by the addition of a new interaction element: computers and robots, intellectual and mechanical resources never before under the direct control of work groups. We need a major program designed to answer questions like:

> What modes of human resource organization and management are most likely to promote individual well-being and organizational productivity?
>
> How can technological change be managed and organized to gain maximum productivity benefits while maintaining and promoting worker well-being and minimizing the social and economic dislocations often associated with new technology?
>
> Are new forms of organization and worker-management relations needed to keep individuals, organizations, and our society viable in an increasingly competitive world market?

Given our failure to apply what past generations of social scientists have learned about group functioning and work behavior (relative to the applications of the Japanese) we probably require a major effort focused both on generating _and applying_ the next round of relevant knowledge. And it would be a great advantage to program this activity so that it creates ready links between basic studies of group processes and applied studies of group behavior in relevant settings.

Health and Human Behavior

Health care currently consumes about 10 percent of our national product, and that figure has been rising rapidly. It is coming to be recognized that a major cause of adverse health outcomes is not the failure of medical technology but the perverseness of human behavior. Thus the next frontier in health research (and especially in medical care cost containment) is likely to lie in research that makes possible an understanding of the behavioral causes of many of our major trauma and serious illnesses: smoking, alcoholism, drug abuse, lack of exercise, poor diet, bad sleeping habits, and failure to use seat belts.

Both longitudinal and field-experimental research are needed to test the predictive association between human attitudes and environments and health-illness behaviors, morbidity and mortality, as well as to develop methods of curtailing behaviors that are deleterious to health and of strengthening behaviors that promote health.

The Influence of Uncertainty on Behavior

In the more tranquil economic and social world of the 1950s and 60s, it may have been possible to model behavioral responses effectively without worrying too much about the way in which uncertainty about the future influenced behavior: The assumption that the future is continuous with the past, while never entirely satisfactory as a basis for modeling behavior, can reasonably be judged to have been more satisfactory then than it is now. Particularly:

A. We need to understand how people form their judgments about the future--what information they use, what weights they give to various types of information, etc.;

B. We need to understand how people cope with certainty, which can be defined operationally as a distribution of possible outcomes with a great deal of dispersion;

C. We need to understand the way in which decision outcomes, and possibly decision processes as well, are modified by the existence of a less stable economic and social environment.

A research agenda in this area clearly includes paying significant attention both to the development of analytical models designed to recognize explicitly the importance of uncertainty, and the generation of behavioral information from which we can begin to understand how decision-makers react to unstable external environments.

Conclusions and Recommendations

These and other social science research topics have a common theme. They suggest that over the next decade the society can achieve major strides in understanding economic and social processes provided it is willing to make the right kinds of investment for a long enough period of time to produce tested and cumulative knowledge. The programmatic areas that I have described are all characterized by the need to pay attention both to the development of theory and method as well as the development of appropriate data-bases. And all of these programs require resources that are large relative to the current levels of funding for social science research within the NSF; they also require stability and continuity of support. If I am right that research programs such as the ones I have described represent areas in which substantial progress can be made, and that a large flow of societal benefits will result, the implication is that future levels of support for the social science research programs within the NSF will have to be substantially larger than they have been during past years.

At present the U.S. is at the cutting edge of research in the social sciences, largely because we have invested substantially more than other countries in the past. But as we know from familiar experience in other areas, that advantage can erode quickly. To prevent that error, I urge this Committee to recommend an authorization for the NSF that restores the Social, Economic and Behavioral Program to the FY1980 funding level.

I wish to thank the Committee for inviting me to submit a statement on this important issue.

RESPONSES BY DR. F. THOMAS JUSTER TO COMMITTEE QUESTIONS ON THE SOCIAL AND BEHAVIORAL SCIENCE PROGRAM AT NSF

Committee on Labor and Human Resources
Senator Orrin G. Hatch, Chairman

Question

In your statement you recommend that the social and behavioral science programs at NSF be restored to the FY 1980 levels. What is the justification for that recommendation?

Response

Let me begin by providing some quantitative perspective on the social and behavioral science programs at the NSF.

The NSF is probably the single most important source of support for basic research, with a mandate to expand the frontiers of scientific knowledge and to support activities which will eventually improve the conditions of people in society.

Of the total number of scientists in the U.S., approximately 34 percent are social scientists; of the total number of scientific problems worth putting resources into, whose resolution would eventually improve the condition of people in society, something like that same fraction must be social and behavioral problems; but of the total resources available to the NSF for scientific inquiry, the social and behavioral sciences are recommended for roughly three percent, down from about five percent two years ago.

The budget recommendation represents a severe misallocation of scientific resources.

It provides just about half the amount of resources, in real terms, as were available in 1980, and is the direct result of the disproportionate cuts first proposed by the Administration over a year ago. It is widely acknowledged that the severe cuts proposed for the social and behavioral sciences were (to quote Mr. Keyworth, the President's Science Adviser) "poor judgment." People at the OMB have said quite explicitly that a great many decisions were made in the early days of the Administration's budget planning, that some of these decisions were inevitably made in haste and, in retrospect, might reasonable be characterized as ill-advised.

On scientific quality, the Director of the NSF, Dr. John Slaughter, has said this year in congressional testimony that the quality of NSF social science research is fully equal to the quality of its natural science research. And the most recent NSF study of the quality of research in the social and behavioral sciences--conducted in the middle 1970's when the social sciences were allocated about five percent of NSF resources--concluded that the quality of projects was, if anything, higher in the social sciences than elsewhere (as judged by the quality of the best proposals that were not funded). If that were true when the social and behavioral sciences represented five percent of NSF resources, it must be substantially more true at their present level of roughly three percent.

More importantly, the budget recommendation will not provide sufficient resources to fund a substantial number of high priority projects that have already been reviewed and approved. As illustrations:

Funding would not be available for measurement-oriented projects like the study of time use (which would contribute significantly to our understanding of productivity, volunteer activity and the underground economy); for development of the environmental data base; for the collection of new data on the quality of American life; and creation of public use data files from governmental archives would be severely restricted.

The recommended program would require severe cuts in major ongoing programs in statistical methods and theory, and would severely limit an important new program designed to assess the quality and validity of survey measures--a methodological program which could increase the efficiency of the billions of dollars spent on data collection activities in both the public and private sectors.

The recommended program severely inhibits projects of a "risk capital" nature: peer review panels are reluctant to fund potentially important but risky ideas in a resource-constrained environment. Thus the development of new lines of inquiry is hampered, with obvious effects on future scientific progress.

There is in addition a large agenda of potential research activities where substantial payoff is both possible and likely, but which are simply not feasible at present funding levels. Illustrative areas are:

Savings behavior. It is crucially important over the next decades to expand investment, and that is ultimately possible only if we can expand saving. Competing theories of saving behavior provide very different perspectives on appropriate policy, and we need to know which perspectives hold up under exposure to the relevant data. The relevant data are not available but could be obtained--at considerable cost.

Health behavior. Most health research focuses on the use of medical technology to treat pathologies. But the evidence suggests that health status is much more influenced by human behavior (smoking and drinking habits, diet, seatbelt usage, stress factors) than by medical treatment. Real progress in both understanding and changing some of these perverse health behavior seems possible.

Productivity. Our knowledge of productivity, and the factors associated with changes in productivity, is severely hampered by the difficulty of studying productivity at the level of the individual firm. One problem is the inadequacy of the data base.

Technology and organizational structure. Much production-oriented behavior takes place in group settings, and the nature of group-oriented interaction will be substantially changed by technologies that will be under the control of production work-groups--e.g., computers and robots. We need a major program of research designed to understand and manage this kind of technical change so as to achieve the potential productivity benefits and at the same time cope with the social and economic dislocations associated with new technology.

Given the importance of the activities that cannot be accommodated within the recommended budget, I urge the Committee to restore funding in the social and behavioral sciences to FY 1980 levels.

That would require adding approximately $18 million--less than two percent of the total NSF budget--to the Behavioral, Biological, and Social Sciences Directorate, earmarked for the social and behavioral science programs within that Directorate.

The resources could either come from adding to the recommended budget total, or by a modest redirection of the increases in the budget--providing slightly smaller increases for most natural science programs in order to free up resources for the social and behavioral programs.

I would prefer adding resources, given the priority that should be accorded to investments in knowledge under present circumstances, but would argue strongly for redirection of the increases if the Committee felt that the budget totals could not be increased.

Question

Your statement refers to the importance of investment in longitudinal data bases, which are very expensive to maintain and which absorb resources over long periods of time. What can you point to as the benefits which would justify NSF investments in these expensive longitudinal data bases?

Response

The social sciences try to gain an understanding of the systematic tendency observable in a variety of human behaviors. The most interesting questions here deal with the process by which individual and aggregate behaviors change, and thus the basic questions are fundamentally dynamic ones. For many problems, the only way to observe those changes is by way of longitudinal study designs--following the same individuals or firms or other units over extended periods of time.

Let me provide two illustrations of what we have learned from longitudinal studies that would not have been learned otherwise.

> Dependency and poverty. In a typical recent year, something like eight percent of U.S. households received some form of welfare payment (defined as AFDC, food stamps, or Supplemental Security Income), while about ten percent are classified as below the poverty line. Since these proportions tended to be about the same each year during the 1970's, most people interpret those results as suggesting that we have a poor and dependent underclass of something like 10 percent of the population. But longitudinal studies of income change over a decade and a half, following the same families and individuals, suggest a strikingly different conclusion:
>
> > During the decade of the 1970's, these studies show that about 25 percent of the U.S. households received welfare during at least one year, while only about 0.7 percent were dependent on welfare during every year.
> >
> > The same story applies to poverty--only 0.7 percent were poor all the time (but they were different from the 0.7 percent who were dependent on welfare all the time), while more than 30 percent of U.S. households were below the poverty line during some one year in a decade.

It is widely thought that welfare dependency is passed on from one generation to the next, largely on the basis of the casual observation that some welfare parents have welfare children. But the longitudinal panel data show that, while poverty is clearly passed on from one generation to the next, there is no persuasive evidence that welfare dependency is passed on. That finding would be more robust (or possibly negated) if we had more years of experience relating to welfare dependency across generations.

A typical view of welfare dependency is that people who receive welfare don't work. The longitudinal panel data suggest that most people who receive welfare also work, and that most welfare recipients get more than half their income from work rather than from welfare.

Voting behavior. Political scientists have traditionally worked with models of voting behavior that compared voters to consumers testing various products on the market, then making up their minds about which products to buy on the basis of product attributes. Thus voters were thought to choose on the basis of policies advocated by, or associated with the candidates.

Longitudinal data on voting preferences and behavior indicate that this is not an accurate characterization of voting behavior for the majority of people. Most voters have their minds made up even before candidates have been selected--people appear to have strong and continuing identifications with political parties and with the ideologies associated with those parties, and those enduring loyalties are the dominant force in voting behavior.

Moreover, these data show that the people most likely to seek information and to be better informed about issues are not "independent" voters with weak party attachments, but voters with strong party attachments: most voters appear to use information as a means of buttressing existing views.

Juvenile delinquency and high school dropouts. There is a well-documented association between juvenile delinquency/crime and high school attendance: dropouts have much higher delinquency rates than others. That finding led to a major effort, during the 1960's, to retain potential dropouts in the school system, on the grounds that an effective retention program would save billions in lower delinquency and crime rates.

Longitudinal data suggest a different perspective. These data show that high school dropout rates are well predicted by earlier experience in school, and that the incidence of delinquency is related to these earlier school experiences. Thus the data provide no support for the proposition that increasing school retention rates would have an impact on delinquency behavior.

Question

What are some of the important national issues where you think social science research would be helpful? And how confident are you that additional resources applied to research in these areas would produce sufficiently reliable knowledge and insights so that the findings could be used to help inform policy?

Response

Let me note a number of areas where social science research can add substantially to illumination of crucially important issues of national policy, as well as provide important scientific advances. Two of them are areas where I am virtually certain that policy-relevant results will be forthcoming, since we understand the problem and lack only resources to attack it. The others are areas where the problems are visible and very real, but where the outcome seems to me less certain.

Areas where research has a high probability of providing useful policy guidance are:

> Saving behavior. It is recognized that an increase in the rate of capital formation is essential to the improvement of productivity performance, and that the required capital formation depends on an adequate flow of private savings. But we have little tested and reliable knowledge about what determines private saving behavior, how saving might change in response to various tax or other stimuli, what will happen to saving as the population ages and as private pension coverage increases, etc.
>
> One important reason for our uncertainty about saving behavior is the virtual total absence of an accurate set of data that measures personal saving, and its change over time, at the level of the individual household. The best such data were obtained almost two decades ago, while the most recent data (of dubious reliability) were obtained in the early 1970's. Unless that gap in knowledge is filled, we will not know much more after the next decade than we know now, and the same unanswered questions will exist.
>
> Health and human behavior. Health care currently consumes about 10 percent of our national product, and that figure has been rising rapidly. It is coming to be recognized that a major cause of adverse health outcomes is not the failure of medical technology but the perverseness of human behavior. Thus the next frontier in

health research (and especially in medical care cost containment) is likely to lie in research that makes possible an understanding of the behavioral causes of many of our major trauma and serious illnesses: smoking, alcoholism, drug abuse, lack of exercise, poor diet, bad sleeping habits, and failure to use seat belts.

Both longitudinal and field-experiment research are needed to test the predictive association between human attitudes and environments and health-illness behaviors, morbidity and mortality, as well as to develop methods of curtailing behaviors that are deleterious to health and of strengthening behaviors that promote health.

The other three areas are ones where substantial progress is likely, but in my judgment somewhat less certain:

Productivity of the firm. Despite all the attention paid to the recent decline in national productivity, our ability to understand productivity change at the level of individual firms is severely hampered by the information base. It is not that we lack data on firms that relate to productivity; but we do not have longitudinal data at the right level of aggregation (the individual firm, where investment decisions are actually made), and the available data are not really well-suited for productivity analysis since they are not designed for that purpose.

Creation of a productivity-oriented data base for individual firms will yield substantial benefits only if it is seen as a long-term effort: analyzing changes in the investment and productivity of the same firms over extended periods of time is generally agreed to be the only effective way to address the problem.

Technology and organizational structure. A great deal of production-oriented behavior takes place in group settings. The nature of much of this group-oriented interaction is likely to be substantially changed in the near future by the addition of a new interaction element: computers and robots, intellectual and mechanical resources never before under the direct control of work groups. We need a major program designed to find out how technological change can be managed and organized so as to gain maximum productivity benefits while maintaining and promoting worker well-being and minimizing the social and economic dislocations often associated with new technology.

Given our failure to apply what past generations of social scientists have learned about group functioning and work behavior (relative to the applications of the Japanese) we probably require a major effort focused both on generating and applying the next round of relevant knowledge. And it would be a great advantage to program this activity so that it creates ready links between basic studies of group processes and applied studies of group behavior in relevant settings.

The influence of uncertainty on behavior. In the more tranquil economic and social world of the 1950's and 60's, it may have been possible to model behavioral responses effectively without worrying too much about the way in which uncertainty about the future influenced behavior: the assumption that the future is continuous with the past, while never entirely satisfactory as a basis for modeling behavior, can reasonably be judged to have been more satisfactory then than it is now.

Particularly, we need to understand how people form judgments about the future--what information they use, what weights they give to various types of information, etc.; we need to understand how people cope with uncertainty, which can be defined operationally as a distribution of possible outcomes with a great deal of dispersion; and we need to understand the way in which decision outcomes, and possibly decision processes as well, are modified by the existence of a less stable econmic and social environment.

Question

Over the years, the NSF has invested quite a lot in basic social science research programs. What have we got for that investment?

Response

The Committee should understand that the accumulation of social science knowledge is typically an incremental affair in which a large number of small steps eventually lead to a totally different perspective --a major gain in knowledge. But there seem not to be the "breakthrough" characteristics that are sometimes found in the natural sciences.

Thus to see what has been learned from past investments in social science research programs, it is helpful to look at differences in our understanding of the economy and society over long spans of time--say, for example, by comparing our present knowledge with what was widely believed around the turn of the century.

> Differences associated with race and sex characteristics. Income differentials between blacks and whites in the U.S. are now explained by differences in the quantity and quality of schooling, in the characteristics of the families and communities in which people are raised, and in aspirations and opportunities; differences between males and females are now explained by differences in labor force experience, career aspiration, and marital attachment. In both cases, there are residual differences which are quite likely attributable to discrimination, either past or present. Within race or sex classes, differences in genetic endowment are recognized as important. But people used to think in terms of genetic factors as explaining differences between blacks and whites or males and females.
>
> Educational achievement. It is now widely recognized that differences among young people in family and community backgrounds have a substantial impact on educational achievement. Thus while the quantity and quality of formal schooling is still thought to be important, people no longer think that what happens in school dominates educational achievement.
>
> Aging. It used to be thought that people lost intellectual and physical capacity as they grew older. Now we know that a good part of the former is simply atrophy--diminution results not from incapacity but from lack of stimulation, and does not appear where adequate stimulation is present.

Living environments for older people. At one time we thought that older people were clearly better off in family environments; then it began to be perceived that communities where older people could spend more time with peers had advantages; now we think that a combination of independence, easy access to family and friends, and the opportunity to interact with either peers or others leads to systematically better outcomes.

Business planning. Over the past several decades, the combination of operations research and linear programming has revolutionized the practices of many large corporations, especially as regards material flows. The same knowledge has had a major impact on certain aspects of military strategy.

Productivity and organizational structure. At one time people thought that productivity differences could be largely explained by differences in amounts of capital available per worker. We now understand that differences in organizational structure and norms play an important role in explaining productivity.

Health. Our perceptions of how to achieve good health efficiently have changed dramatically over the decade. In relatively poor societies, public health measures like innoculation have made an enormous difference in life expectancy by virtually eliminating certain causes of illness or death. In some areas, we have made dramatic improvements in medical technology for treating certain types of pathologies. But one of the most important insights we have now is that perverse behavioral phenomena (diet, smoking and drinking habits, seatbelt usage, the incidence of stress, etc.) are one of the most important causes of morbidity and mortality. The solution to improving health status thus depends importantly on understanding these perverse behavior.

Well-being. In earlier and simpler times, changes in well-being were typically thought about as having largely economic and material roots. We have now begun to understand the importance of the environment, of nonmarket productive activity that takes place within households, and of the crucial role of family and community structure in people's well-being.

Prediction of major social and economic phenomena. Despite appropriate cautions about the failure of social science in prediction, it is still true that we are vastly better able to understand and predict the path of business activity, of variations over time in birthrates, the outcome of an election, etc., than was the case earlier in the century. The visible shortcomings of social science predictions should be assessed against the standard that we have come to expect a good deal, and often fall short of that expectation.

Crime. To note one area in which we seem to have accumulated largely negative knowledge, we seem to be at the point in analysis of criminal activity where we have discredited a lot of theories but have not been able either to understand the roots of crime or to devise strategies for reducing it.

Statement

of

Arthur C. Gentile, Ph.D.
Executive Director
American Institute of Biological Sciences

to the

Committee on Labor and Human Resources
United States Senate

April 15, 1982

Mr. Chairman and Members of the Committee:

I am grateful for the opportunity to present the views of the American Institute of Biological Sciences on the FY 1983 budget for the National Science Foundation (NSF) to this Committee. The Institute is a consortium of thirty-eight professional societies in biology with an aggregate membership of over 60,000 scientists. Since the vast majority of these scientists are at universities and colleges and are engaged in basic research and since the major source of support for this research is the NSF, we have a long-standing and continued interest in all legislation which impacts upon the Foundation.

We were pleased to hear Dr. Keyworth's statement before the House Committee on Science and Technology where he reaffirmed the administration's support for funding basic research. He stated "Support of science and technology - especially basic research - is a long-term investment that represents an essential element in the foundation of a healthy economy". However, his statement that the growth that science and technology have enjoyed for so many years cannot continue in a period of fiscal austerity may be challenged. In a report of the National Science Board (Science Indicators, 1980) it is shown that federal support for all R&D has shown essentially no increase in constant dollars since 1968. Civilian R&D as a percent of the GNP has increased only 10% in the U.S. during the past fourteen years, while in West Germany it rose 30% and in Japan it rose 35%. These figures are reflected in the differences in manufacturing productivity among the three nations. Basic research, which amounted to only 15% of the R&D budget in 1981, is most vulnerable to budget reductions, while at the same time it is the source of some of the most unexpected and dramatic technological gains. In biology, for example, the results of research in genetic engineering, have resulted in impressive technological gains, and this field is only in its infancy.

Research in biology represents some of the most rapidly advancing areas in science today. These include studies on biological systems which may be used to address major problems in health and agriculture, as well as provide answers to the prevention of the further deterioration of our environment. It is therefore, gratifying that the proposed NSF budget for FY 1983 for research in the biological sciences shows a 6.1% increase over the current year. However, this increase is not a real one even if one accepts the administration's estimate of inflation in 1983 of 6.5%, a figure which may prove to be highly optimistic.

If, on the other hand, we should be grateful for small blessings in this era of ever-decreasing budgets, as has been suggested, it might be well to concentrate on specific areas of the NSF budget which require your attention. Science education appears to have been targeted for extinction by the current administration. Science education, which had an actual budget of $71 million in FY 81, is budgeted for $21 million in FY 82 (including funds restored by the Congress). For FY 83 the administration requested only $15 million, an amount which maintains the NSF Graduate Fellowship program but eliminates all other educational activities. We were pleased to see the authorization for science education increased to $45 million by the House Committee on Science and Technology, and urge you to endorse this level of support.

It is well documented that science, mathematics and technological education in the United States, both at the secondary and college levels, is in a precarious decline. Entering freshmen in college have shown, by national test scores, a severe deterioration in mathematical and academic skills. What makes this deterioration so frightening is that the future economic and physical welfare of our citizens, as well as our future national security is dependent upon a supply of highly trained scientists and engineers. The United States is losing the technological edge it once enjoyed over other countries around the world, and the lead time to correct this precipitous decline is running out. Countries such as Japan, USSR, and West Germany have built into their educational systems a heavy emphasis on science and mathematics. Japan produces more engineers per capita than the United States; the conclusion is obvious.

The current crisis in science and engineering education is the result of many factors, including the attitudes of parents, society, and students, as well as an absence of national direction. The appointment of a special commission to advise the President on science education is a step in the right direction. Its recommendation, however, will not be forthcoming for some time. In the interim we should not abandon our modest efforts to improve science education by eliminating its budgetary support. If we do, we shall face increasing difficulties in securing talented and highly trained minds for the scientific disciplines in the future.

Another facet of science education is to promote public understanding. Indeed, the increase in the number of popular science magazines and the success of television science programs indicate that the public is not only supportive of science education, but thirsty for knowledge of science. If the public is being asked to support science and all its ramifications, it should be provided an opportunity to learn what science is doing, how it is being done, and why. To the average American, science has become too arcane, and this condition must be remedied if we are to expect popular support for scientific endeavors.

The problem of modernizing research equipment and research laboratories is another that is not addressed in the FY 1983 budget request. In the biological sciences, the current budget calls for $5.2 for biological instrumentation, an increase of $0.9 million over the current level of support. These funds will be used to support the cost of purchasing instruments needed for specific research projects on NSF grants. The program proposed by the NSF to modernize research facilities did not survive the budget process fo- FY 1982, although the Senate Committee on Labor and Human Resources did authorize $14.5 million for this program.

In the U.S., most basic research is conducted in university laboratories. Modern research is highly specialized and sophisticated and requires equally sophisticated and expensive instrumentation. Over the last fifteen years, funds for instrumentation have been severely curtailed and today, university laboratories fare poorly in comparison to their counterparts in government and industry. The deterioration of university instrumentation is threatening the capacity of even the best institutions to conduct research and provide quality training. The lack of state-of-the-art instrumentation and attempted use of obsolete, frequently malfunctioning instruments are bound to impede research efforts. In addition to instrumentation needs, research programs cannot operate at full capacity without adequate facilities, such as laboratories, animal facilities, and greenhouses. Many of these facilities were built when universities were expanding during the 1950's and 1960's and are becoming old, while replacement and renovation funds are difficult to obtain from other sources. We urge you to give careful consideration to this need.

American Educational
Research Association

April 14, 1982

Honorable Orrin G. Hatch
Chairman
Committee on Labor and Human Resources
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

On behalf of the 14,000 members of the American Educational Research Association, I request that you place the enclosed statement in support of National Science Foundation's science education programs in the hearing record (April 15) before the Labor and Human Resources Committee.

Our statement strongly requests that the Congress take the leadership to mandate that the National Science Foundation comply with its statutory obligation to support science education. We believe that in the coming year funds should be focused on three essential program areas covering research in science and mathematics instructions, pre-college staff development and training for science teachers, and both graduate and undergraduate college support.

In addition, we are recommending that the Committee require the National Science Foundation to develop a full plan and budget for science education for FY84.

Thank you for your kind attention to this matter.

Sincerely yours,

David H. Florio

David H. Florio, Ph.D.
Director of Governmental
and Professional Liaison

DHF/jcw

1230 SEVENTEENTH STREET, N.W., WASHINGTON, D.C. 20036 (202) 223-9485

American Educational
Research Association

April 15, 1982

STATEMENT PRESENTED TO THE

**SENATE COMMITTEE ON
LABOR AND HUMAN RESOURCES**

The Need to Save Science Education In The National Science Foundation

THE UNITED STATES IS A FIRST-RATE INTELLECTUAL, POLITICAL, INDUSTRIAL, AND MILITARY POWER. THE NATIONAL GOVERNMENT OF SUCH A COUNTRY DARE NOT ABDICATE ITS RESPONSIBILITIES TO PROVIDE THE ESSENTIAL EDUCATION NEEDED TO RETAIN ITS INTERNATIONAL POSITION. THE SYMBOLIC EFFECT OF THE ADMINISTRATION'S PLANS FOR NSF SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION ARE DAMAGING ENOUGH. THE CONGRESS MUST ACT WITH DISPATCH TO CORRECT THIS IMPRESSION OF NEGLECT AND RESTORE SUBSTANTIVE EFFORTS TO STRENGTHEN THE MINDPOWER OF AMERICA'S FUTURE.

The Administration's budget for NSF science education and the decision to abolish the NSF Science and Engineering Education Directorate is both beyond understanding and, taken with other cuts in education programs, apparently mindless. The programs of the SEE Directorate were (and can be) particularly focused on several of the most salient problems of American education: 1) a shortage of math and science teachers, 2) instructional problems in math and science at the pre-college level, and 3) personnel and instrumental constraints on the ability of higher education to prepare the next generation of scientists, engineers, and mathematicians. If ever there was a need of national leadership by the federal government in the area of science education, the time is now. NSF, instead, has formed a commission to study the problem. Over the past several

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years, the National Academy of Science, NSF and the Department of Education, and comparative studies of the United States, Japan, Germany, and the Soviet Union have already documented the problem. A new NSF commission may be useful in identifying areas of collaboration between schools, colleges, government, business, industry and others in the private sector; however, it is no substitute for a focused set of essential science education programs.

THE FY82 ADMINISTRATION BUDGET AND CONGRESSIONAL APPROPRIATIONS ALL BUT ELIMINATED THE MOST PROMISING PROGRAMS IN NSF SCIENCE EDUCATION. The Administration has proposed another 25% in Education Department (ED) programs, on top of the 15% already imposed; ED will not take up programs eliminated in NSF. IT IS NOT TOO LATE FOR THE CONGRESS to take the leadership in mandating that NSF provide programmatic support in three essential and productive S.E.E. areas.

I. A PROGRAM OF RESEARCH AND ANALYSIS IN SCIENCE AND MATHEMATICS EDUCATION

This program would focus on the improvement of pre-college math and science instruction. ONE OF THE MOST PROMISING PROGRAMS OF S.E.E. WAS THE RESEARCH IN SCIENCE EDUCATION (RISE) PROGRAM. The RISE effort, on hold but not destroyed, is essential if math and science courses, particularly at the jr. and sr. high school levels, are to effectively increase math and science literacy. The RISE program cannot be supported by the ED's National Institute of Education which has a frozen spending authority (FY82-4) -25% below FY80 and a current appropriation -28% below its original FY81 allocation. Work in progress, and greatly threatened by the Administration's proposals, include the following:

COGNITIVE SCIENCE APPLIED TO PROBLEM SOLVING, PHYSICS INSTRUCTION, MATHEMATICS LEARNING, ETC. Work at the University of Pittsburgh, Carnegie-Mellon University, and University of Massachusetts at Amherst is focusing on a variety of student learing challenges -- e.g., learing from error, unlearning incorrect problem-solving strategies, anxieties about math and science courses, etc.

COMPUTER LITERACY. Use of microprocessors in secondary school mathematics and science courses has been studied to determine effective ways to introduce students to computers and provide them the essential technological understandings to prepare them for careers or advanced education.

LEARNING TECHNOLOGIES AND TEACHER SHORTAGES. A recent nation-wide study of teaching shortages reported that 34 states have shortages or "severe shortages" in mathematics teachers, and over 40 states have severe shortages in physics teachers in our schools. Studies must focus on ways to expand the human resources that we do have in these areas and explorations were underway in the use of computer assisted instruction for critical math and science courses.

MATHEMATICS TEACHING STRATEGIES. School mathematics, with a mandated emphasis on "basics", has been successful in improving computation skills. Research studies have identified the problems associated with declines in math test scores at the jr. high level. Schools have neglected instruction in the development of problem solving skills. S.E.E. studies are showing how teachers can use the familiar to improve conceptual thinking and problem solving.

LITERACY AND SCIENCE LEARNING. Research studies at Michigan State University and the University of Georgia have focused on students' ability to comprehend from text and to translate what is read into scientific concepts. These studies are leading to modifications in school and college science and math text books.

MATHEMATICS LITERACY AND IMPROVED THINKING AND INSTRUCTION. Studies on 9th grade mathematics learning have identified concepts which are essential to mathematics learning. Studies have discovered learning problems with inferential thinking and approaches to mathematics problem solving. New instructional strategies are being developed to assure that students have the essential "mathematics literacy" tools.

Three points need to be made concerning the need to revitalize the research/analysis program in the S.E.E. Directorate:

1. no other level of government will support such studies and drastic reductions in other education R&D programs and the social and behavioral sciences in NSF make it unlikely that other parts of the federal government will focus on these critical teaching and learning problems;

2. it is essential that a continuous assessment of the status of math and science education is known and S.E.E. has the ability to provide such assessment;
3. there is a danger that educators and scientists may move ahead in instructional development and education software ("courseware") programs without the needed understanding of real classrooms and student learning abilities, developments, and problems. This was done in the 1960s and resulted in little used equipment, poorly prepared teachers, and curricula inappropriate for actual school and college classrooms.

II. A PROGRAM OF STAFF DEVELOPMENT AND SUMMER INSTITUTES FOR MATH AND SCIENCE TEACHERS

There are cost-effective ways to reach practicing math and science teachers. Summer institutes, staff development programs administered by science and mathematics teaching organizations, and collaborative efforts with teacher education institutions, state education agencies, and technical assistance organizations can be implored to bring important information and teaching strategies to practicing educators at the pre-college level.

III. HIGHER EDUCATION PROGRAMS FOR UNDERGRADUATE AND GRADUATE STUDENTS

The remaining S.E.E. funds have been almost exclusively devoted to graduate fellowships. The Congress should take this opportunity to direct limited funds to a more favorable balance between graduate and undergraduate education. In addition to fellowships, NSF should focus on the needs of undergraduate science and engineering education: laboratories, equipment, instruction, and faculty retention.

The Need to Mandate a Plan for the Future

It is recognized that, in the short run, the FY83 program for S.E.E. must be focused on the above areas of most pressing need. Even when so targeted, we understand that only limited (about $50 million) will be allocated for FY83. It is, therefore, essential that the Congress mandate that the National Science Foundation, in collaboration with the science, mathematics, and engineering communities, present a plan for a national program to address problems in science education. The plan should be specifically addressed to pre-college instruction, the math and science teaching force, R&D in math and science education, undergraduate and graduate math, science and engineering education as they relate to:

- scientific and mathematical literacy
- innovation and development in the private sector
- technological literacy in the workforce
- military personnel and the specific industrial capacity to deliver essential military equipment (including the potential drain on the non-military innovation, development, and production)
- international trade and economic revitalization

The plan should also include a programmatic plan for the S.E.E. Directorate with an appropriate budget request for FY84 and the years beyond.

Staff Contact: David H. Florio, Director, Governmental & Professional Liaison, A.E.R.A.

Statement by

the Association of American Colleges

on

the Fiscal Year 1983 National Science Foundation

Budget Reauthorizations

before the

Committee on Labor and Human Resources

United States Senate

April 15, 1982

The Association of American Colleges is pleased to submit to the Senate Committee on Labor and Human Resources a statement of our position regarding the 1983 authorization bill for the National Science Foundation. AAC represents nearly 600 higher education institutions, both two and four year, public and private, which are committed to the enhancement and improvement of liberal education. As both science and mathematics education are integral to a liberal education, AAC's members find issues before you today of primary concern. They are particularly interested in the authorization for funding of the Directorate for Science and Engineering Education.

The cutbacks in funding for science and engineering education as proposed by the Administration come at a time in our nation's history when our position of world leadership in science and technology is threatened. Shortages of engineering and scientific manpower both contribute to the weakening of our industrial productivity and to the shortages of technologically trained personnel reported by the Department of Defense within the ranks of our armed forces. In the long term it is illogical to expect scientific research and technological innovation to flourish without sound basic education in science and technology for young men and women who will become the scientists and engineers for tomorrow. Manpower shortages will not be overcome by support for research alone, but will be remedied only through improvement of scientific and technological education.

Beyond the national security and economic considerations, there are broader concerns for the future of our country. In 1959, the President's Science Advisory Committee cautioned that a democratic society cannot conduct its affairs amid prevailing popular ignorance of science and technology. In the words of the committee:

> "Science affects the life of every contemporary man every day. It conditions decisions that need to be made by government on many matters, including national defense, foreign policy, and public health. It affects the decisions made by individuals on business problems, on selecting a community in which to live, on choosing an automobile, a record player, or perhaps even a dentifrice. If an individual is ignorant of science he must guess what to do or else believe what he is told. Even if he is told what to do by an expert, he has no way to check on this advice or even to understand it. This unhappy predicament is precisely that of most citizens of the United States today. Their fate in important matters and trivial matters alike may thus be decided without their participation. And it will not be otherwise so long as they remain ignorant about science and technology."

The committee went on to quote Alfred North Whitehead's admonition that advance in science is absolute, that unprepared societies which do not keep pace with it are doomed. Without widespread public understanding and support, the committee, warned, that effort could not be consistently maintained. Indeed, the very essence of our culture and society is being determined by scientific progress and technological change, and all participants in our democratic decision-making process are becoming increasingly dependent on technical and scientific knowledge. Education in science and technology is waning at the very moment when the need for knowledge of scientific principles and technology is ever greater for those wishing to exert leadership. Unless all of our citizens, not just scientists and engineers, master the new technologies, the new technologies may very well master them.

Our problems and concerns are national in scope and will require strong national leadership. The National Science Foundation was founded and authorized in 1950 to "initiate and support basic scientific research and science education programs at all levels." Since that time, strong educational programs at the elementary and secondary, undergraduate, and graduate levels have been developed, implemented and operated. Our existing situation now demands leadership from NSF in science education, and this requires adequate support. We should not, at the first sign of financial difficulties, abandon long-standing policies and programs.

In light of these concerns, AAC respectfully urges this Committee to carefully consider the budget for science and engineering education at the National Science Foundation, and to adopt as a minimum the $45 million funding level recently approved by the House Science and Technology Committee for science education programs. This, we believe, represents the rock bottom amount necessary for continuation of the requirements of NSF's charter.

As evidence of its concern for science education, the membership of the AAC passed the following resolution at its 1982 annual meeting.

RESOLUTION ON SCIENCE EDUCATION

WHEREAS leadership in scientific research which is fundamental to improved economic productivity and national security depends on adequate basic education in the sciences;

WHEREAS science education is an integral part of liberal education as well as being an essential prerequisite for a technically-competent and scientifically-oriented work force;

WHEREAS both the extent and quality of science education in the nation's schools and colleges have seriously declined; and

WHEREAS withdrawal of federal funds from support of science education will further impair the quality of science education and threaten deterioration in the quality of basic research and national productivity and security;

THEREFORE, be it resolved:

That the President of the Association of American Colleges and its Board of Directors, in efforts supportive of basic research and science education, strongly support adequate funding of science education and, in particular, oppose further reductions in the federal commitment to science education;

That the President of the Association work with officers of other educational associations to urge reconsideration by the Administration of the decision to eliminate federal involvement in science education; and

That the President of the Association convey this resolution at a timely moment to the chairmen of the appropriate committees of the Senate and the House of Representatives of the U.S. Congress.

DOCUMENT

TO

COMMITTEE ON LABOR AND HUMAN RESOURCES

OF

THE UNITED STATES SENATE

IN REGARD TO

1983 AUTHORIZATION
FOR
THE SCIENCE EDUCATION COMPONENT
OF
THE NATIONAL SCIENCE FOUNDATION

PREPARED BY

DR.JOHN W. LAYMAN
PRESIDENT
THE AMERICAN ASSOCIATION OF PHYSICS TEACHERS
EXECUTIVE OFFICE
GRADUATE PHYSICS BUILDING
SUNY AT STONY BROOK
STONY BROOK, NEW YORK 11794

DATE: APRIL 15, 1982

As President of the American Association of Physics Teachers I wish to express to your Committee my dismay at the short-sighted policies of the present Administration in effectively eliminating all activities in Science Education in spite of the congressional mandate that this be part of the obligations of the National Science Foundation. My view is shared by leaders in many scientific societies as refelected in past resolutions passed by the American Institute of Physics Governing Board when only cutbacks in the levels of support were contemplated rather than total elimination.

The establishment of a Special Commission on Science and Engineering Education by the National Science Board can do little to address an issue already carefully documented.

Physics and mathematics are two areas where the shortage of qualified secondary teachers is the greatest. The American Association of Physics Teachers has formed a Temporary Committee on The Crisis in Science and Engineering Education which will not only set policies and seek solutions within the Association but prepare proposals suitable for the NSF and other agencies at the Federal level. We are convinced that these problems require federal intervention and leadership as well as efforts by science and science teaching societies, colleges and universities, and state and local education authorities.

I submit this letter not to highlight what the AAPT may be doing, but to indicate the level of concensus that exists among the many science societies. Close collaboration is occurring between the American Association of Physics Teachers, the American Physical Society, the American Association for the Advancement of Science, and the National Science Teachers Association. Dr. F. James Rutherford will appear before this Committee and Sarah E. Klein

President of the NSTA will present written testimony. Their well documented description of the present state of science education and their proposed solutions are fully supported by the American Association of Physics Teachers.

It is clear from all present information that the Administration does not recognize the gravity of the situation and that Congress and the Senate must provide the primary leadership at the federal level.

There is clearly a critical shortage of qualified physics and mathematics teachers at the secondary levels and in engineering and computer science at the university level. Unless something is done to address these problems we will surely limit our country's technological and defense capabilities and the future well being of all of our citizens.

Statement by

John Wright

President

University of Alabama in Huntsville

on

The Fiscal Year 1983 National Science Foundation

Budget Authorizations

on behalf of the

American Association of State Colleges and Universities
American Association of Community and Junior Colleges
American Council on Education
American Educational Research Association
American Psychological Association
Association for the Advancement of Psychology
Association for Affiliated College and University Offices
Association of American Colleges
Association of American Universities
Association of Catholic Colleges and Universities
California State University
Council of Graduate Schools
Council of Independent Colleges
National Association of Independent Colleges and Universities
National Association of Schools and Colleges of the United Methodist Church
National Association of State Universities and Land-Grant Colleges
National Council of Teachers of Mathematics
State University of New York

before the

Committee on Labor and Human Resources

United States Senate

April 15, 1982

My name is John Wright and I am President of the University of Alabama in Huntsville, a position I have held for approximately four years. Prior to assuming the presidency at UAH, I served as the Chief Academic Officer for the West Virginia Board of Regents and Dean of the College of Arts and Sciences at West Virginia University and at Northern Arizona University. In addition to my administrative roles, I have served on the faculty at West Virginia Wesleyan College, Northern Arizona University, and West Virginia University holding a rank of Professor of Chemistry. I have received a Ph. D. degree in Chemistry from the University of Illinois in 1951 and did post-doctoral work at the University of London in 1962 and at the University of Michigan in 1965. I have also worked as a research scientist for seven years in industry and have been a member of the staff at the National Science Foundation. I also have been a member of the Army Science Board.

I am pleased to have the opportunity to submit testimony to this Committee on the FY 1983 National Science Foundation Authorization bill, with particular emphasis on the Science and Engineering Directorate.

I represent 354 member institutions of the American Association of State Colleges and Universities, and am currently Chairman of its Committee on Science and Technology. My testimony is also supported by the following associations:

American Association of Community and Junior Colleges
American Council on Education
American Educational Research Association
American Psychological Association
Association for the Advancement of Psychology
Association for Affiliated College and University Offices

Association of American Colleges
Association of American Universities
Association of Catholic Colleges and Universities
California State University
Council of Graduate Schools
Council of Independent Colleges
National Association of Independent Colleges and Universities
National Association of Schools and Colleges of the United Methodist Church
National Association of State Universities and Land-Grant Colleges
National Council of Teachers of Mathematics
State University of New York

Our institutions are located throughout the United States, and include two colleges in Utah, three in Vermont, five in Indiana, seven in Florida, nine in Oklahoma, four in Connecticut, two in New Hampshire, seven in Alabama, thirteen in North Carolina, eleven in Massachusetts, ten in West Virginia, one in Rhode Island, nine in Missouri, nine in Michigan, and eight in Ohio.

With a combined enrollment of over 2½ million students, the 354 state colleges and universities of AASCU enroll one out of four of all baccalaureate degree students in the country. Our institutions play a major role in our nation's science effort. Many students who ultimately pursue advanced degrees in scientific and technical fields receive their basic undergraduate training at our institutions. A large portion of the nation's future elementary and secondary school science and mathematics teachers are educated at AASCU colleges and universities. These teachers must be able to communicate the knowledge and skills that will enable our youth to live in an increasingly complex and technology-dependent society. AASCU institutions award close to 30% of the B. S. degrees in engineering annually.

Mr. Chairman, it gives me great pleasure to associate myself with the forceful and eloquent statement presented to the Committee by F. James Rutherford, Chief Education Officer of the American Association for the Advancement of Science.

The past year has been an increasingly bleak and frustrating one for those of us interested in, and concerned with, the future scientific and technological strength of the United States. The Administration's decision to cut funding for all science and engineering education programs, with the exception of the graduate fellowships program, is an example of fiscal considerations--reduced budgets--interfering with perceived national goals--adequate supply of scientific and technological manpower.

For this reason, I urge you to reconsider the Administration's budget request for science and engineering education at the National Science Foundation. As a guideline, I would urge you to adopt at least the level of spending contained in the bill H. R. 5842, recently voted upon by the House Science and Technology Committee. The additional sum of money in H. R. 5842 for science and engineering education, $30 million, is far lower than the actual need, but takes into account current budgetary restraints; the levels in H. R. 5842 are necessary if we are to maintain the vestiges of a national system of science and engineering education and to fulfill the mandate of the Foundation's charter.

THE CHANGING INTERNATIONAL ENVIRONMENT: THREATS TO U. S. TECHNOLOGY

The proposed cutback in funding for science and engineering education comes at the very time in our history when the U. S.'s position of world leadership in science and technology is being severely challenged. The proposed cuts, we believe, ultimately will jeopardize our national security and economic well-being by undermining American industrial, commercial, and military strengths. D. Allan Bromely, Retiring President of the American Association for the Advancement of Science, recently noted that "to expect scientific and technological progress while abandoning efforts at improving science and technological teaching in our schools is illogical and a disservice to the nation's interests."

The severity of the situation was highlighted in a recent study by SRI International that compared the education and employment of scientists and engineers in the U. S. and the U.S.S.R. Based on its findings the report concludes that "there is a need for concern in the U. S. and that concerns should be manifested in a systematic and comprehensive review of our training of Americans at all levels of education for an increasingly scientific and technological world. Such a review will undoubtedly indicate that changes are required, and we should be prepared to make them . . . If anything less is accepted as a national objective, then there is cause for alarm."

I would like to cite some examples that cause me to be alarmed about our nation's future scientific and technological base.

- Manpower shortages in engineering and computer specialists are contributing to the decline in productivity and the decline in U. S. share of world trade. Between 1963 and 1977 productivity increased in the manufacturing industries of the United Kingdom by 51%, of West Germany by 114%, of Japan by 197%, and of the United States by 39%. During that same time the U. S. share of world trade in manufactured items declined from 21% to 16%, while Japan's share increased from 8% to 15%.
- The Department of Defense reports that it has problems recruiting and retaining civilian and military engineers; the Air Force reports a shortage of 1,100 engineers in ranks, and a shortfall of 114,000 engineers over the next ten years. It also notes that it is more and more difficult to find officers and NCO's who are qualified to be trained to operate increasingly sophisticated military hardware.
- In Japan the number of degrees granted to engineers in recent years has surpassed the number granted in those same years in the U. S., though Japan's population is one-half of ours. The Soviet Union graduates more than twice as many scientists and engineers as does the U. S. and has almost five times as many engineering students. The U. S. ranks third behind the Soviet Union and Japan in the proportion of engineering graduates in the population.
- About 1.4 million scientists and engineers are going to be needed for fill growth and replacement demands by 1990.

- By 1990 half of the workers in any factory may well be engineers and technicians who will require massive retraining.

Against this ominous background, our nation's science and engineering education establishment is beset by a range of problems as stated by Dr. Rutherford. This Committee is all too familiar with the litany--shortages of math and science teachers in elementary and secondary schools, as indicated in the data presented by the National Science Teachers Association, inadequate laboratory facilities in colleges, lack of research experiences for undergraduate students, rising undergraduate engineering enrollments coupled with shortages of engineering faculty. You, as well as I, know that our system of science and engineering education is in a state of crisis. What we lack however, is a nationwide commitment and agenda to deal with these problems.

THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

I strongly believe that the National Science Foundation must play a leading role in restoring the health of American science and engineering education.

When the National Science Foundation was established in 1950, it was authorized and directed to "initiate and support basic scientific research and programs . . . and science education programs at all levels." The educatonal mandate of the National Science Foundation has been an integral part of our nation's scientific establishment since that time. It was clearly reaffirmed when Congress in 1979 rejected proposals to move the science education programs out of the National Science Foundation to the newly created Department of Education.

Now in 1982, this dual mission of the Foundation is being abrogated with the Administration's proposals to significantly reduce all education programs. The higher education community, collectively and individually, testified last year before various Congressional committees urging the rejection of the Administration's plan as a shortsighted and strategic error. We believe that the reasons for the Foundation's charter in science and engineering education remain as valid today as they did in 1950 and that adequate funding for science and engineering education must continue.

We were somewhat encouraged last year by Congressional decisions that restored limited amounts of funds for the National Science Foundation to conduct the education programs that are mandated in its charter. The need for science and engineering education programs is great, yet the monetary resources available this year (a little over $20 million) will be disproportionate to that need. I urge Congress to once again reject the Administration's FY 1983 plan to eliminate all science and education programs, except fellowships, and to provide funding for a range of education activities at the Foundation.

What role should the National Science Foundation play in correcting the disparity between available resources and perceived needs? One approach would be for a clear and unequivocal call for increased funding of science and engineering education programs. Such a call coming from an eminent group of scientists would serve to dramatize the problems at hand and the range of solutions necessary to deal with them.

In contrast, however, the Foundation has proposed the establishment of a Special Commission on Science and Engineering Education. For the record, I would like to introduce a letter written by Allan W. Ostar to the NSF expressing our concerns with this approach.

We do not need a Commission to *study* a problem, the dimensions of which are already clear. We should not *wait* 18 months for this Commission to make its recommendations. We need *action* by Congress *now* so that American science and engineering education may be restored to a system of excellence. We need a Congress that will take this action and support science and engineering education in our schools, colleges and universities with adequate levels of funding.

THE REDUCTION OF SCIENCE AND ENGINEERING EDUCATION FUNDING: ITS EFFECT

What will be the likely long-term effect on our nation if the science and engineering education programs of the National Science Foundation are eliminated?

First, the size of the pool from which future scientists and engineers will be drawn will be severely reduced. By 1995 the proportion of the total population in the 18-24 age range will be 25 percent less than it was in 1980. If, as we approach the end of this century, the number of scientists and engineers is not to decrease in absolute terms--let alone increase to meet what by then will be an increasing industrial and military demand--the *proportion* of this population prepared for higher education in science and engineering must increase. But if federal science career motivation programs are cut off, we can expect a smaller proportion, and hence a smaller *number* of young children to be attracted to science and engineering careers.

Many of those children who do become interested in science when very young will be turned away by the poor quality of science teaching they encounter in their junior and senior high schools. Without federal help science and mathematics teaching will be unable to keep current with new developments. Without federally funded in-service institutes high school science and mathematics teachers will fall further behind in their subjects, and their already damaging isolation from ongoing contact with research and the real world of science will be made more complete. Without federal assistance colleges and universities will be unable to upgrade instructional laboratory equipment, introduce important new scientific and educational concepts to undergraduates and, in general, improve the quality and effectiveness of undergraduate science education. Every year this persists will be a year that hastens the increasing shortfall of scientific human resources.

Second, new entrants into the nation's technical and managerial work force will, in the aggregate, be increasingly underprepared to function effectively. Even now the schools are failing to turn out graduates who can cope with the increasingly technical nature of work in commerce, industry, and the military. To allow the situation to become still worse by withdrawing the only federal effort that addresses the educational roots of our productivity/security concerns, is to incur enormous national (if not federal) costs. Each year that the system fails, the "educational national debt" grows, ultimately to be paid by the public. Industry and the military must provide science and mathematics education to make up for school failures. To the extent that our business and defense establishments are unable to rectify previous science education failures, productivity lags further, inflation worsens, public costs soar. The effect is cumulative. Each year that we let this problem go unattended by national leadership and resources, we mortgage the economy, and face the unhappy, totally unnecessary prospect in a few years of either investing in expensive "re-education" or paying the price of ill-prepared workers year after year.

If the federal role in education is now diminished virtually eliminating NSF involvement, then there is little chance of turning things around. The price we will pay--in terms of scientific career development and a technically competent workforce will be out of proportion to the money saved.

The present crisis presents the best opportunity that has existed in several years to refocus and sharpen the NSF effort. However, it would be unwise, and inefficient, to phase out all NSF science and engineering activities while this reconceptualization is taking place. Momentum would be lost, valuable programs interrupted, talent dispersed, and attention diverted to the logistics of phasing out the budget, facilities and personnel of a doomed enterprise. In this regard, the recent reorganization of the Science and Engineering Education Directorate into an Office of Scientific and Engineering Personnel and Education.

Science education at NSF must be strengthened so that it can be restored as a more effective partner in sharing with state and local agencies and public and private institutions the responsibility for, and costs of, putting science education back on its feet in this country and keeping it there. In order to achieve such a revitalization it will be important for certain problems to be dealt with thoughtfully and imaginatively by the NSF, the National Science Board, OMB, and Congress.

In this regard, the House Committee on Science and Technology has asked NSF to submit its plans for a revitalized science and engineering program to it by October 15, 1982. Though we are opposed to any delays, I would hope that your Committee will also ask for such a plan within this timetable so that the agency might proceed with improvements in our nation's science and engineering education system.

Recently, AASCU surveyed its membership to learn how science and engineering education cuts would affect course offerings in these areas. I include for your information in the attached appendix a summary of these comments. Without an exception, the institutions agreed that it would be extremely difficult to continue to offer those science and engineering education courses that had been previously supported by NSF.

I would like to give you two examples here of how small amounts of money have benefitted our institutions. Similar benefits have also been reported by our nation's private colleges and universities.

- $20,000 to Ferris State College in Big Rapids, Michigan will be used to refurbish physiographic equipment already on hand for use in biology courses. Refurbishment, in this case, rather than replacement will lead to substantial improvements in instruction at a savings over the cost of new equipment. It should be noted that the institution is required to match the $20,000 NSF contribution.

- $25,745 to Ball State University in Muncie, Indiana will be used to develop a course for non-science majors in using scientific information for formulating opinions on complex technical public policy issues, such as the use of nuclear fission in commercial power generation. Again, the institution must acquire further support from other sources to supplement the NSF award.

I thank you for the opportunity to present this testimony to you. I would be pleased to respond to any questions that you might have.

aascu

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January 15, 1982

Mr. John B. Talmadge
Chairman, Ad Hoc Planning Group
NSB Special Commission on Science
  and Engineering Education
National Science Foundation
Washington, DC 20550

Dear Mr. Talmadge:

The American Association of State Colleges and Universities appreciates the opportunity to respond to the National Science Board's proposed plan to establish a Special Commission on Science and Engineering Education.

The past year has been an increasingly bleak and frustrating one for those of us interested in, and concerned with, the future scientific and technological strength of the United States. The Administration's decision to cut funding for all science and engineering education programs, with the exception of the graduate fellowships program, is an example of fiscal considerations--reduced budgets--interfering with perceived national goals--adequate supply of scientific manpower. We were somewhat encouraged by Congressional decisions that restored some limited amount of funds for the National Science Foundation to conduct the education programs that are mandated in its charter. The need for science and engineering education programs is great, yet the monetary resources available this year will be disproportionate to that need.

What role should the National Science Foundation and the National Science Board play in correcting this disparity between available resources and perceived needs? One approach would be for a clear and unequivocal call for increased funding of science and engineering education programs. Such a call coming from an eminent group of scien-

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Cable Address: AASCU Washington, D.C.

tists and national leaders would serve to dramatize the problems at hand and the range of solutions necessary to deal with them. In contrast, however, the Foundation and the Board have selected an approach that will result in little concrete improvements in our scientific education system.

There are two reasons why the proposed Commission will fail to adequately address what is rapidly becoming a critical situation.

First, the proposed scope of activites and focus of the Commission does not recognize that our educational system is a system. To isolate and examine secondary school education without paying equal attention to primary and higher education ignores the fact that all parts of the American educational complex are interrelated.

The situation in our secondary schools is, indeed critical, but it cannot fruitfully be examined without considering the problems that precede the secondary school. Students at the elementary school level must be adequately prepared in mathematical skills and thinking, and sufficiently motivated and inspired in the sciences. If not, they will arrive in the secondary schools without the proper foundations or interests to pursue more advanced scientific and mathematical courses. In that sense, a Commission which concentrates its efforts on the secondary schools is entering the process six or seven years too late.

By focusing on the secondary schools the proposed plan also ignores the relation that higher education bears to the other educational components. With the removal of federal assistance to colleges and universities, secondary school graduates will find themselves entering higher education institutions with inadequate laboratories and out-of-date curriculum. Higher education's role in training elementary and secondary school teachers, initially and later through in-service and summer institutes, has been an important one. The Commission's approach fails to recognize this training relationship.

One problem in the teacher training system--the problem of attracting and retaining teachers when industrial opportunities and salaries are more attractive--seriously threatens to erode the quality of elementary and secondary school science teachers. The proposed Commission model will be able to do little more than note these trends.

Second, the proposed Commission plans to solve a national problem by local efforts and with local resources. The Statement on NSF Activities in Science and Engineering Education as adopted by the NSB at its 228th Meeting on August 20-21, 1981, states that, "The U. S. requires an educational system equal to its needs and opportunities in science and technology. The NSB is gravely concerned that the Nation is far less well prepared to meet the needs and challenges of the future than is necessary . . ." Throughout this and other supporting documents it is clearly recognized that our scientific educational system and its deficiencies are national problems.

In the Rationale for the Commission it is stated that "in most countries this concern of maintaining science and technology has led to a vigorous effort to upgrade and focus education programs." One only has to look at the systems, and the successes, of two of our industrial competitors in the world market--Japan and West Germany--to understand how the infusion of monetary support and national attention has resulted in a scientific educational system far superior to ours. The Rationale continues by stating that the diversity of our educational system complicates such an approach since problems must be "solved primarily at the level of the local school system."

The message conveyed by this approach is that national leaders will examine national problems, make recommendations, and coordinate activities . . . all this to be done with local dollars. How the local school districts will provide these dollars is unclear. These localities are experiencing severe fiscal constraints which will hamper their efforts.

In your letter of December 29, 1981, you observed that the "Commission's actions have the potential for having more impact than its final report." We agree with that observation and hope that the Commission will act in accordance with our recommendations.

The Association, its staff and member institutions, pledge their cooperation in helping you to formulate an action plan that will begin to solve the inadequacies in Science and Engineering education.

Without such action our nation's economic strength, technological base, and military security will ultimately be threatened.

Sincerely,

Allan W. Ostar

Allan W. Ostar
President

AWO: pjl

AMERICAN ASSOCIATION OF STATE COLLEGES AND UNIVERSITIES

INSTITUTIONAL COMMENT ON THE IMPACT OF SCIENCE EDUCATION

North Carolina Central University:

Under an earlier LOCI grant, they developed a set of computer-assisted homework exercises for Introductory Sociology. The concept was to give sociology students laboratory experience in a similar manner to students in the biological and physical sciences where the laboratory begins in the introductory course. The lessons, called Programs from Introductory Sociology (PROFITS), were referred and accepted for distribution by CONDUIT, and are in use at over 100 institutions of higher education in the United States.

At NCCU under a second LOCI grant, they developed computer-assisted homework lessons for teaching sociological statistics. These nine lessons, having been student-tested for three years, are now ready for review and testing by CONDUIT, which has asked to review them. The lessons, called CASE (Computer-Assisted Sociological Exercises), have been used to aid 50 black students at NCCU over a three-year period. Again, national distribution is expected.

State University College at Buffalo:

In a concentrated, six-week summer program 24 high-ability Western New York high school juniors learned how to develop an environmental impact statement and then prepared such a study of a Buffalo area site.

Called by the Buffalo Evening News environmental news editor "one of the best and most complete assessments of Times Beach," the extensive student report would have cost the city at least $50,000 had a professional firm prepared it. Total cost of the educational project was the $17,550 NSF grant, which paid three Colleges at Buffalo faculty, provided supplies and honoraria for 11 special speakers, and supplied a $2 per day commuter allowance for the high school participants. Other costs, such as those for college computer services, were absorbed by the college.

For three weeks the students studied two local case histories--the Love Canal leaking of industrial toxic waste and the West Valley nuclear fuel reprocessing plant--and learned ecological principles and methodologies. The final three weeks were spent in the on-site study of Times Beach.

Oral and written presentations of their findings and recommendations were made by the students to a panel of city officials, educators, and ecological specialists.

For at least 16 years National Science Foundation teacher-training programs have been conducted at the college, and 18 programs have been directed by a professor of chemistry, who most recently supervised a four-week, summer '81 workshop on "Physical Chemistry for Secondary School Teachers of the Biological Sciences."

Revolutionary advances in biological knowledge having come largely from chemists exploring complex structures at both the cellular and sub-cellular levels of organization, it has become essential for biology teachers to be throughly familiar with the principles of physical chemistry. Accordingly this course, taught to 30 Western New York teachers in grades 9-12 by three faculty with expertise in molecular biochemistry, physical chemistry, and biological principles, was proposed and received a $13,404 NSF grant. The college provided all classroom space and laboratory equipment.

The summer program was reinforced throughout the following academic year by faculty visits to the teachers' schools as often as requested.

The value of providing science teachers with such opportunities to increase and update their knowledge is evident considering that the current New York State Biology Syllabus contains topics in molecular biology that require a deeper understanding of chemistry principles than ever before, yet few NYS biology teacher-training programs require a course in physical chemistry.

Recognizing the increasing need for computer literacy, the College at Buffalo has embarked on a two-year project to develop five instructional modules whose focus is an interactive computer simulation of an environmental issue.

The module subject areas are population, energy, air and water pollution, toxic and hazardous waste, endangered species, and land use for undergraduate environmental science courses.

In the grant proposal that received a NSF $26,720 award and that also has State University of New York support amounting to $13,134, the college pointed out that students taking computer-enriched courses will benefit in several ways. Using the computer to simulate complex systems will increase insight into the nature of such systems and will afford the non-science major an increasingly wanted opportunity for firsthand experience with a computer.

University of Northern Iowa:

A possible casualty if the cuts are made is a one-of-a-kind program in Iowa that has reached almost 600 elementary and secondary school teachers throughout the state. The Pre-College Teacher Development Program is unique in that it offers a wide selection of short courses to give math and science teachers a look at new developments in science and refresher courses in basic science.

UNI faculty members go to outlying areas to teach the courses which include such topics as the body and drugs, energy concepts, microcomputers and hand-held calculators.

Tennessee Tech University

In the fall of 1981, for example, Tennessee Tech's electrical engineering department received a $30,000 Local Course Improvement grant to purchase component parts to build portable digital lab stations for use in student experiments, expanding the curriculum in digital systems design. The university provided an additional $23,000 plus release time for two faculty members to work on the project and design course material for use with the stations. About 150 students will benefit from the program each year.

A $144,000 NSF Comprehensive Assistance to Undergraduate Science Education (CAUSE) grant received in fiscal 1980 was used in the development of an undergraduate interdisciplinary real-time digital system program. The university added $74,000 to the grant amount. The three-year interdisciplinary project involves six engineering departments and four non-engineering departments--biology, earth sciences, chemistry, and computer science. In the past, students had been unable to do real-time computer work due to the cost of standard computer equipment. The project has permitted the development and acquisition of four "stand alone" microcomputer systems at about one-tenth of the cost of standard systems. The laboratory will permit undergraduate students to learn data acquisition systems currently used by large processing industries.

Northeastern Illinois University

In 1977, funding in the amount of $50,000 was received by the Department of Geography and Environmental Studies for the training of 30 Chicago-area secondary school teachers in remote sensing principles (the use of photographs of the earth which are taken from satellites and on space missions) and their applications.

In 1977, funding in the amount of $5,000 was received and matched by an equal sum from Northeastern for the purchase of introductory electronics equipment for the Physics II laboratory.

In 1979, the Department of Biology received a grant of $11,300 which was matched by an equal sum from the university for the purchase of a variety of equipment which allows a class of 24 students to conduct individual experiments utilizing the physiograph, a versatile instrument which provides the capability of studying a wide range of standard physiological phenomena in human and laboratory animals.

Since the equipment was acquired, approximately 360 students have taken Vertebrate Physiology, the course for which the equipment was purchased.

Appalachian State University

The general objective of the project is to provide mathematical modeling experiences for undergraduates at Appalachian State University in the mathematical and physical sciences; where real work problems are presented in non-mathematical terms, the mathematical formulation by the student is emphasized problems considered invite solution attempts based on a variety of mathematical techniques and approaches, the time frame for problem solution is suitable for local needs, and studies are suitable for results of "solutions" to be presented in written project reports.

This proposal seeks funding in the amount of $22,114 to design, implement and evaluate a new course for prospective middle school teachers. The course will teach basic physics and astronomy, and the key feature will be the use of inexpensive "string and sticky tape" laboratory equipment and demonstration throughout. The purpose will be to develop student confidence in their ability to develop, and utilize in their later teaching, an abundance of laboratory experiences which cost very little. The experiments will be devised from materials commonly available from any household, supplemented with very inexpensive commercial materials. Typcially, a middle school teacher in the public schools has virtually no science budget, and this course will prepare teachers to cope with that reality. A second purpose is to give these teachers a positive feeling about science, brought about by their own success and confidence in doing physics with simple equipment. This positive feeling will, in turn, be passed on to their students.

This proposal requests funds for the acquisition of components of a nuclear radiation spectrometer system to upgrade several upper level undergraduate courses in the area of radiation detection and measurement.

The proposed equipment will be used to continued the improvement of our senior level experimental physics course, to facilitate the expansion of our junior level radiation physics course, and to help establish a meaningful laboratory component in our senior level medical physics course.

Stockton State College

Thank you for your request for information about the effect of NSF science education programs on Stockton State College and the South Jersey community. South Jersey is a rural environment and Stockton State College is the four-year school within about 50 miles. As such it is an important resource to the community. Stockton has received a variety of NSF science education grants in the past.

In previous years, Stockton received funds for the training of secondary school teachers in the local rural area. These teachers were given instructions by the Stockton faculty enabling them to become aware of changes in their disciplines. They were then able to bring this information back to their high schools with them.

Stockton was founded only ten years ago and a very small fraction of the population in this area is college educated. The college has been having substantial impact on the community and NSF Science Education funding has been part of that impact.

NSF Science Education funds were also used for equipment purchases and course improvement. These funds substantially changed our course offerings in physics and enabled us to do a better job in training our students.

Sam Houston State University

Dr. John R. Hilliard, Jr., professor of Life Sciences, directed the program for secondary level science teachers. It totaled $33,157, with 43 participants. Twenty-six schools in 16 different school districts were represented.

"Growing out of this project, six large and ambitious projects in developing wooded areas on school property into outdoor learning centers were initiated and are now being used in instructional programs," says Hilliard.

The project lasted from August, 1977 to May, 1979.

"The investment of an average of $800 in taxpayers funds per participant for funding the overall program has resulted in a widespread influence in improved science education in southeast Texas," says Hilliard.

Dr. Paul A. Loeffler taught in the program for junior high students. He explains the necessity for the program:

"The program was developed to address a problem that exists in, but which is not unique to, East Texas. Many of the area school districts are small rural districts that are generally poorly funded and which, therefore, cannot provide adequate teachers or facilities necessary for satisfactory science training.

"The resultant limited exposure to adequate science training, particularly at the junior high level, often channels students away from later science training and possible careers in science.

"Furthermore, since the enrollment of these districts include a substantial percentage of minorities and disadvantaged youth, a disproportionate number of minorities and disadvantaged students are inadvertently guided away from the sciences."

"This program is very effective in inspiring young students to select the pre-college science curriculum that will allow them to grow as tomorrow's scientists," he said.

University of Nebraska at Omaha

Dr. John Karloff, associate professor of Mathematics and Computer Science. Dr. Karloff is presently the recipient of a fellowship to the State University of New York at Stony Brook and Brookhaven National Laboratory as a NSF Faculty development visitor. The goal of Dr. Karlof's fellowship is to develop an expanded department of Applied Mathematics at U.N.O.

> "Since there is a shortage of applied mathematics professors and a large demand for applied mathematics college graduates, completion of the program should improve the capabilities of my students in meeting current employment requirements."

In citing the needs of current employment, Dr. Karlof predicts the usage of the program he develops in training seminars for local business. Funding for the seminars would be needed and further Applied studies would also need financial assistance. Dr. Karlof feels most strongly that the budget elimination of Science and Engineering Education programs would have a detrimental effect on the less wealthy institutions.

California State University, Northridge

During academic year 1980-81 at CSUN, the "Women in Science and Engineering" program, funded in part through a NSF education directorate grant, recruited, retrained and placed in professional engineering apprenticeships, 52 women who had been out of the scientific labor force for many years.

Participating industry sponsors in that program have included: The Aerospace Corporation; Bunker Ramo Corporation, Electronic Systems; General Motors Assembly Division; Grumman Aerospace Corporation, Pt. Mugu; Hughes Aircraft, Missile Systems Group; Litton Data Systems; Lockheed California Company, Burbank; Northrop Corporation, Electronics Division; Rockwell International, Energy Systems Group; and TRW, Inc , Defense and Space Systems Group.

University of Montevallo

-- At least 300 Alabama high school teachers upgraded their classroom skills through the Pre-College Science Teachers Programs and the College Science Improvement Programs at the University of Montevallo. One of the programs was conducted ten summers. When the program began in the early 1960s, many Alabama high school chemistry teachers were not certified in the specialty because of a shortage of teachers. The program prepared them for their teaching assignments and encouraged them to earn their master's degrees. Ironically, when a public junior college system opened in the mid and late 1960s, the newly trained high school chemistry teachers became the new junior college chemistry teachers.

Southwest Texas State University

To provide funds to buy equipment necessary for establishment of a first-rate Plant Econogy course and to modernize pre-existing plant anatomy and biometry courses.

The plant ecology program is established and will continue to be funded by the Biology Department. Plant Anatomy and Plant Ecology courses will be continued. Without NSF funding, none of these courses could have been equipped as well as they now are with modern equipment.

This grant enabled the Chemistry Department to buy a research chromotography instrument that could not have otherwise been purchased. This purchase allows Dr. W. Rudzinski to conduct research with an instrument with unique capabilities. It further released equipment of lower capability for graduate and undergraduate instruction that would not have been feasible if Dr. Rudzinski would have continued to use the pre-existing department equipment.

State University of New York College at Brockport

At the State University of New York College at Brockport, $321,915 in National Science Foundation grants have made possible projects in chemistry, earth sciences, and mathematics/computer science.

A total of 40 faculty members, 8,545 students in natural science courses, and more than 6,000 community members have benefitted from these grants. (The 184 science and college level teachers attending a Brockport science education program each have about 35 students in their class for a total community population of 6,440.)

NSF provided $258,773 for Project CAUSE - Comprehensive Assistance to Under-graduate Science Education. This grant made it possible for Brockport to host a conference on microcomputers in higher education that was attended by 142 professionals in higher education, secondary education and business. The conference helped advance the state of the art in undergraduate instruction using computer technology in several disciplines. The proposal identified 2,900 people per year who will receive instruction under this particular NSF grant.

Western Oregon State College

Western Oregon State College received a NSF CAUSE (Computer Assistance to Undergraduate Science Education) grant in May 1980 for a three-year program emphasizing "Infusion of Computer Science into Liberal Arts and Teacher Education." We are completing the second year of the grant, and we expect the funding to continue for a third year.

Goals of our program include expanding student exposure to computers; expanding faculty knowledge and use of computers; adding an introductory course in computer literacy for the general student; establishing an academic computer laboratory; and developing the curriculum for a minor program in computer science.

So far, 23 faculty members have participated in the program and have received training in ways to introduce use of computers into their regular courses. Projects have been developed in a wide range of disciplines, including mathematics, chemistry, physics, economics, psychology, language, music, education, biology, geology, social science, physical education, library, and dance.

More than 500 students so far have benefitted from the introduction of computer instruction in such areas. Ten more faculty members are scheduled to receive training this coming summer.

Courses have been added in computer literacy and computer programming and more than 600 students have participated in these courses. College administrators are currently considering introducing computer literacy into the required core curriculum for all college students.

CAUSE grant funds have allowed us to add a computer laboratory that contains 11 APPLE II microcomputers available for use by faculty and students. Progress also is underway in developing a computer science minor for our curriculum.

Overall, then, the NSF grant has helped WOSC make great strides in bringing computers to our students. Because we have traditionally been a teacher education institution (60 percent of our students major in education), we expect the benefits of the CAUSE grant to have long lasting effects upon the future teachers we are training. Special applications for computers in secondary education and special education are being explored by faculty on our campus.

Georgia State University

Our Department of Chemistry has been supported by the NSF Science education program CAUSE. This support was used to develop a computer-assisted instructional center for undergraduate chemistry students at the university.

The center consists of 30 micro-computers now in place in the Chemistry Department. It is used as an auto-tutorial system enabling large numbers of students to deal directly with a computer in solving chemistry problems in their study of the subject.

Approximately two-thirds of the funds for the center came from NSF, and the remaining one-third from university sources.

Clarion State College

Since 1969 Clarion State College, Clarion, Pennsylvania has received numerous grants from the National Science Foundation for the purpose of improving science education. Most grant programs have been designed to provide inservice education experiences for teachers of science at the elementary, middle and junior high school, and high school levels. The topics have included elementary science curriculum innovations, environmental science, and human biology. Additional NSF programs designed to disseminate innovations in science education have also been presented by the college. These have included the dissemination of science curricula for the junior high school and curricula in the environmental sciences and, most recently, a program designed to promote science among elementary school principals.

Approximately 600 teachers and school administrators have been directly involved as participants in these science programs. Many more have benefitted by the "trickle-down" effect.

The college has found past programs to be very beneficial in meeting the needs of middle grade teachers of science. The individuals, teachers, and administrators that have participated in past programs have communicated positive perceptions concerning the planning, organization, and presentation of the activities that they experienced. The follow-up services and interest provided by the college personnel have proved extremely valuable to our district personnel during the implementation of the ideas generated during their participation.

A healthy respect for federally funded programs has been developed, through willingness to become involved.

During the past several years, Clarion State College has provided valuable and varied in-service programs for their district, with many teachers participating.

In the past several years, Clarion State College has provided a number of valuable educational experiences in the sciences for teachers in Western Pennsylvania. These programs have been possible due to financial support from the National Science Foundation and by the excellent cooperation of concerned teachers.

Clarion State College has done tremendous work in the preparation of teachers for science education. This is and has been possible because of the dedicated teachers and the monetary support of the National Science Foundation. The students and teachers have benefitted greatly from programs sucn as these.

The college has made a major contribution to the Otto-Eldred Schools in two ways. The Clarion graduates employed by this district have excellent backgrounds in science due to the high quality of college preparatory courses. Secondly, the in-service programs provided by Clarion have been practical, pertinent, and have led to positive student and teacher attitudes toward science.

The National Science Foundation could assist Clarion in having a broad impast upon teachers, pupils and the community in general concerning a heightened awareness of one's responsibility for human biology. It is hoped that funding will be made, and that the local schools will be enabled to provit by future in-service.

Over the last several years, at least 40 teachers from the North Hills District have had the benefit of working with the Clarion staff in developing science curriculum for their district. The staff has been instrumental in developing the elementary science program and has had programs for middle school and high school teachers. There has been very good cooperation in assisting the district in the development and implementation of the sciences program.

The Oil City Area School District also supports the inservice proposal for reasons of past experience with Clarion State College. NSF programs in the past have been carried out with enthusiasm and efficiency. Teachers and administrators have participated and the Oil City students have definitely benefited.

During the various training projects, teachers have learned to design learning environments for hands-on experiencing by children; teachers have become more willing to individualize instruction and to try laboratory activities; teachers have increased their competence with science content, and teachers have been motivated to present science lessons to their students.

Overall experience with other NSF programs administered by Clarion State College has been most positive. Some of the teachers have availed themselves of the opportunity to improve their own teaching strategies. Since many teachers find continuing education to be financially difficult, finding funding sources is of utmost importance so that science teachers may have the opportunity to continue to grow professionally.

The potential impact of a project such as that on Human Biology for teachers of science in grades 5 through 8, could be tremendous. It would impact on teachers, pupils, parents and the community in general. In isolated Appalachian regions, Clarion State College has been instrumental in providing many quality science programs for the teachers, administrators and pupils. The programs have provided improved science curricula, teacher in-service programs and technical assistance. These services would have been impossible without the many successful science grants and excellent leadership available.

Oakland University

Three recent NSF grants that have helped the Department of Chemistry to keep its curricular offerings reasonably up to date: The RULE grant provided funds to offer improved upper level laboratories and to train faculty to permit the introduction of courses in industrial chemistry and polymer chemistry. The ISEP grant was the latest of a series of NSF Instructional Scientific Equipment grants that the department has received. This particular grant enabled them to add experiments involving thermal analysis to several laboratory courses. The CAUSE grant was as the program title implies, a comprehensive program to improve every aspect of undergraduate chemistry instruction. The net effect of NSF support to this department cannot be over estimated. Oakland University has essentially been able to buy $2 worth of equipment for every $1 of state money. As you know, modern equipment is essential for the training of chemists. Such equipment not only continues to increase in cost but has a useful lifetime of five to eight years. Many of the major equipment items are approaching or have passed their expected life times at the university. Without future NSF support to replace obsolete or wornout items, and add newly developed equipment, other sources of funds will have to be found or the training of future chemists at Oakland University will slowly decline in quality.

The University of North Carolina at Charlotte

The Chemistry Department received a Liquid Chromatograph for undergraduate instruction at a cost of $12,250. The number of students benefited annually is 168.

Under an Urban Environmental Studies Project funded thorugh a $16,942 grant, the university provided an enrichment opportunity for 25 gifted 11th grade students who studied at the university on weekends while still in school. They learned about some of the contemporary problems of cities and studied possible solutions. That program is terminating.

The College of Engineering sponsored a program to encourage undergraduate research through a grant of $15,176. That program is terminating. Five engineering students engaged in research through the program.

A $17,946 grant supported a program to strengthen and update junior and senior high school physical science teachers in the Charlotte area. Some 20 teachers participated. The future of that program would be in doubt without the funding.

Science Education Figures
submitted by Senator Edward M. Kennedy

Appendix table 1-1. Scientists and engineers' engaged in R&D per labor force population, by country: 1965-80

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
	Scientists and engineers[1] engaged in R&D per 10,000 labor force population															
France	21.0	23.3	25.3	26.4	27.2	27.3	27.8	28.1	28.4	28.8	29.3	29.9	30.3	NA	NA	NA
West Germany	22.7	22.4	24.9	26.2	28.4	30.9	33.8	36.0	37.8	39.1	41.0	41.7	44.3	NA	NA	NA
Japan	24.6	26.4	27.8	31.2	30.8	33.4	37.5	38.1	42.5	44.9	47.9	48.4	49.9	49.4	NA	NA
United Kingdom	19.6	NA	NA	20.8	NA	NA	NA	30.4	NA	NA	31.3	NA	NA	NA	NA	NA
United States	64.1	66.1	66.1	66.9	65.9	63.6	60.6	58.2	56.9	56.3	56.4	56.7	57.7	58.3	59.2	60.4
U.S.S.R. (lowest)	44.8	47.1	50.7	53.5	56.5	58.4	63.0	66.5	73.5	74.5	78.2	80.7	81.3	82.9	84.2	85.9
U.S.S.R. (highest)	48.2	51.4	55.3	58.8	62.1	64.2	69.1	73.2	81.5	82.9	87.5	90.9	91.5	93.3	94.9	96.7
	Scientists and engineers engaged in R&D (in thousands)															
France	42.8	47.9	52.4	54.7	57.2	58.5	60.1	61.2	62.7	64.1	65.3	67.0	68.0	NA	NA	NA
West Germany	61.0	60.0	64.5	68.0	74.9	82.5	90.2	96.0	101.0	102.5	103.9	104.5	111.0	NA	NA	NA
Japan	117.6	128.9	138.7	157.6	157.1	172.0	194.3	198.1	226.6	238.2	255.2	260.2	272.0	273.1	NA	NA
United Kingdom	49.9	NA	NA	52.8	NA	NA	NA	76.7	NA	NA	80.7	NA	NA	NA	NA	NA
United States	494.5	521.1	534.4	550.4	555.2	546.5	526.4	518.3	518.4	525.1	534.9	549.2	573.9	597.3	621.2	645.0
U.S.S.R. (lowest)	521.8	556.5	607.8	650.8	699.8	733.3	804.2	862.5	966.7	995.8	1,061.2	1,113.7	1,140.0	1,179.0	1,214.0	1,254.0
U.S.S.R. (highest)	561.4	607.6	862.6	751.2	767.5	806.9	881.8	950.1	1,072.1	1,108.0	1,187.6	1,254.5	1,282.0	1,327.0	1,368.0	1,412.0
	Total labor force (in thousands)															
France	20,381	20,522	20,676	20,744	20,996	21,465	21,638	21,817	22,083	22,282	22,310	22,440	22,468	NA	NA	NA
West Germany	26,887	26,801	25,950	25,968	26,356	26,668	26,725	26,655	26,712	26,215	25,323	25,088	26,044	25,209	NA	NA
Japan	47,870	48,910	49,830	50,610	50,980	51,530	51,860	51,940	53,260	53,100	53,230	53,780	54,520	55,320	NA	NA
United Kingdom	25,498	25,632	25,490	25,378	25,375	25,308	25,122	25,195	25,546	25,602	25,798	26,098	26,324	26,360	NA	NA
United States	77,178	78,893	80,793	82,272	84,240	85,903	86,929	88,991	91,040	93,240	94,793	96,917	99,534	102,537	104,996	106,821
U.S.S.R.	116,494	118,138	119,893	121,716	123,584	125,612	127,672	129,722	131,610	133,600	135,767	137,987	140,140	142,214	144,201	146,068

[1] Includes all scientists and engineers engaged in R&D on a full-time-equivalent basis (except for Japan whose data include persons primarily employed in R&D and the United Kingdom whose data include only the Government and industry sectors).

NA = Not available

NOTE: Estimates are shown for most countries for latest years and for the United States for 1966 and 1967. A range has been provided for the U.S.S.R. because of the difficulties inherent in comparing Soviet scientific personnel data.

SOURCES: Organisation for Economic Co-operation and Development, *Labor Force Statistics, 1965-1976* (Paris: OECD, 1978), p. 23, Quarterly Supplement; Department of Labor, *Employment and Earnings*, February 1981, p. 13.

France: Délégation Générale à la Recherche Scientifique et Technique, unpublished statistics.
Japan: Scientific Councelor Embassy of Japan, Washington, D.C., unpublished statistics.
United Kingdom: Cabinet Office, The Central Statistical Office, London, unpublished statistics.
West Germany: Bundesministerium fur Forschung und Technologie, unpublished statistics.
United States: National Science Foundation, unpublished data.
U.S.S.R.: Dr. Robert W. Campbell, *Reference Source on USSR R&D Statistics, 1950-1978*, 1978; Steven Rapawy, *Estimates and Projections of the Labor Force and Civilian Employment in the U.S.S.R., 1950 to 1990*, Foreign Economic Report No. 10, U.S. Department of Commerce, 1976, p. 19; Robert W. Campbell, *Soviet R&D Statistics 1977-1980*, National Science Foundation, 1981.

See figure 1-1.

Appendix table 1-2. U.S. bachelors degrees and U.S.S.R. diplomas conferred by higher educational institutions, by major field of study: 1960-1979

Field of study	1960		1965		1970		1975		1976		1977		1979	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.
	Number (in thousands)													
All fields total	394.9	343.3	538.9	403.9	833.3	630.8	987.9	713.4	997.5	734.6	993.0	751.9	1000.6	790.0
Science and Engineering total	89.4	162.5	109.3	211.8	147.6	328.5	161.4	370.9	164.4	383.4	168.7	397.9	179.7	416.9
Physical and life sciences and mathematics[1]	45.3	25.1	65.7	25.6	91.4	39.7	96.5	44.9	98.2	46.3	97.5	47.8	93.6	49.8
Engineering	37.8	102.9	36.8	152.3	44.8	230.5	47.3	272.1	46.7	280.4	49.7	291.4	62.8	306.8
Agriculture	6.3	34.5	6.8	33.9	11.4	58.3	17.6	53.9	19.5	56.7	21.5	58.7	23.2	60.3
Non-S/E fields	305.5	180.8	429.6	192.1	685.7	302.3	826.5	342.5	833.1	351.2	824.3	354.0	820.9	373.1
	As a percent of the 22/23 year old population[2]													
All fields total	17.6	7.8	18.1	13.3	23.9	19.3	26.0	16.4	25.6	17.1	23.5	16.8	24.1	16.4
Science and engineering total	4.0	3.7	3.7	7.0	4.2	10.1	4.3	8.5	4.2	8.9	4.3	8.9	4.3	8.7
Physical and life sciences and mathematics[1]	2.0	.6	2.2	.8	2.6	1.2	2.5	1.0	2.5	1.1	2.5	1.1	2.3	1.0
Engineering	1.7	2.3	1.2	5.0	1.3	7.1	1.2	6.2	1.2	6.5	1.3	6.5	1.5	6.4
Agriculture	.3	.8	.2	1.1	.3	1.8	.5	1.2	.5	1.3	.5	1.3	0.6	1.3
Non-S/E fields	13.6	4.1	14.4	6.3	19.6	9.3	21.8	7.9	21.4	8.2	20.8	7.9	19.8	7.8

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[1] Figures for the U.S.S.R. are estimates made by SRI International to approximate the U.S. definitions.

[2] Based on 22-year-olds for the U.S. and on 23-year-olds for the U.S.S.R., because of the differences in average length of years required to graduate from higher education.

SOURCES: *Earned Degrees Conferred*, National Center for Education Statistics; *National Economy of the U.S.S.R. in 1970 and 1979*; U.S.S.R. Population Data from Foreign Demographic Analysis Division, U.S. Department of Commerce, U.S. population data from Population Division, U.S. Bureau of Census; Catherine P. Ailes and Francis W. Rushing, *Training and Utilization of Scientists and Engineers: U.S. and U.S.S.R.* (Washington DC: SRI International, 1980), pp. 75-76.

See figure 1-2.

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Appendix table 1-3. National expenditures for performance of R&D as a percent of gross national product (GNP) by country: 1961-81

Year	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
	Ratio of R&D expenditures to Gross National Product[1]					
1961	1.38	NA	1.39	2.46	2.73	NA
1962	1.46	1.25	1.47	NA	2.73	2.64
1963	1.55	1.41	1.44	NA	2.87	2.80
1964	1.81	1.57	1.48	2.29	2.96	2.87
1965	2.01	1.73	1.54	NA	2.89	2.85
1966	2.06	1.81	1.48	2.32	2.88	2.88
1967	2.13	1.97	1.53	2.30	2.89	2.91
1968	2.08	1.97	1.61	2.27	2.82	NA
1969	1.94	2.05	1.65	2.22	2.71	3.03
1970	1.91	2.18	1.79	NA	2.63	3.23
1971	1.90	2.38	1.84	NA	2.48	3.29
1972	1.86	2.33	1.85	2.06	2.40	3.58
1973	1.76	2.22	1.89	NA	2.32	3.66
1974	1.79	2.26	1.95	NA	2.29	3.64
1975	1.80	2.38	1.94	2.05	2.27	3.69
1976	1.77	2.29	1.93	NA	2.26	3.55
1977	1.76	2.32	1.92	NA	2.24	3.46
1978	1.76	2.37	1.93	2.11	2.23	3.47
1979 (prelim.)	NA	2.36	NA	NA	2.25	3.44
1980 (est.) ..	NA	NA	NA	NA	2.33	3.47
1981 (est.) ..	NA	NA	NA	NA	2.37	NA
	R&D expenditures (national currency in billions)[2]					
1961	4.5	NA	275.5	.68	14.3	NA
1962	5.4	4.5	319.3	NA	15.4	5.2
1963	6.4	5.4	368.3	NA	17.1	5.8
1964	8.3	6.6	438.1	.77	18.9	6.4
1965	9.8	7.9	508.6	NA	20.0	6.9
1966	11.0	8.8	576.6	.89	21.8	7.5
1967	12.2	9.7	702.5	.93	23.1	8.2
1968	13.1	10.6	877.5	.99	24.6	9.0
1969	14.2	12.2	1,064.7	1.05	25.6	10.0
1970	15.0	14.8	1,355.5	NA	26.1	11.7
1971	16.6	18.0	1,532.4	NA	26.7	13.0
1972	18.3	19.2	1,791.9	1.31	28.4	14.4
1973	19.8	20.5	2,215.8	NA	30.7	15.7
1974	23.0	22.3	2,716.0	NA	32.8	16.5
1975	26.2	24.6	2,974.6	2.15	35.2	17.4
1976	29.8	25.7	3,320.7	NA	38.9	17.7
1977	33.2	27.7	3,651.3	NA	42.9	18.3
1978	37.5	30.5	4,045.9	3.44	48.0	19.3
1979 (prelim.)	NA	32.9	NA	NA	54.2	20.2
1980 (est.) ..	NA	NA	NA	NA	61.1	21.3
1981 (est.) ..	NA	NA	NA	NA	69.1	NA

(continued)

Table 1-3. (Continued)

Year	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
	Gross National Product (national currency in billions)					
1961	328.4	333.0	19,852.8	27.5	524.6	NA
1962	367.2	360.5	21,659.5	28.9	565.0	197.2
1963	412.0	382.1	25,592.1	30.8	596.7	206.8
1964	456.7	419.6	29,661.9	33.5	637.7	223.2
1965	489.8	458.2	32,981.6	36.0	691.1	242.1
1966	532.0	487.4	38,872.8	38.4	756.0	260.1
1967	574.8	493.7	45,896.8	40.5	799.6	282.0
1968	630.0	535.2	54,576.8	43.8	873.4	NA
1969	734.0	597.7	64,513.6	47.1	944.0	329.6
1970	783.6	679.0	75,523.9	51.6	992.7	362.6
1971	873.1	756.0	83,166.0	57.8	1,077.6	394.8
1972	961.3	827.2	96,883.1	63.8	1,185.9	401.8
1973	1,121.3	920.1	117,257.9	74.1	1,326.4	429.4
1974	1,284.4	986.9	139,219.3	84.0	1,434.2	453.1
1975	1,455.2	1,034.9	153,126.3	104.7	1,549.2	471.8
1976	1.677.8	1,125.0	171,735.6	124.6	1,718.0	498.6
1977	1,881.8	1,197.2	190,426.3	142.3	1,918.0	528.8
1978	2,135.1	1,287.5	209,248.2	162.5	2,156.1	556.8
1979 (prelim.)	NA	1,393.8	NA	NA	2,413.9	587.9
1980 (est.)	NA	NA	NA	NA	2,626.1	614.5
1981 (est.)	NA	NA	NA	NA	2,920.0	NA

[1] Calculated from unrounded figures.

[2] Gross expenditures for performance of R & D including associated capital expenditures except for the United States where total capital expenditure data are not available. U. S. estimates for the period 1972-80 show that the inclusion of capital expenditures would have an impact of less than one tenth of one percent on the R & D/GNP ratio.

NA = not available.

NOTE: The latest data may be preliminary or estimates.

SOURCES: International Monetary Fund, *International Financial Statistics*, vol. 30 (May 1977); vol. 31 (May 1978); vol. 31 (August 1978); vol. 32 (January 1979); and vol. 33 (August 1980).

France: Délégation Générale à la Recherche Scientifique et Technique, unpublished statistics.
Japan: Scientific Councelor Embassy of Japan, Washington, D.C., unpublished statistics.
United Kingdom: Cabinet Office, The Central Statistical Office, London, unpublished statistics.
West Germany: Bundesministerium für Forscheng und Technologie, unpublished statistics.
United States: Science Resources Studies, National Science Foundation, unpublished statistics.
U.S.S.R.: Robert W. Campbell, *Reference Source on Soviet R & D Statistics, 1950-1978*, 1978, and Robert W. Campbell, *Soviet R & D Statistics 1977-1980*, National Science Foundation, 1981.

See figure 1-3.

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Appendix table 1-4. Estimated ratio of civilian R&D expenditures[1] to gross national product (GNP) for selected countries: 1961-81

Year	France	West Germany	Japan	United Kingdom	United States
	Estimated civilian R&D expenditures as a percent of GNP				
1961	0.97	NA	1.37	1.48	1.20
1962	1.03	1.14	1.46	NA	1.23
1963	1.10	1.26	1.43	NA	1.29
1964	1.34	1.38	1.47	1.49	1.31
1965	1.37	1.53	1.53	NA	1.33
1966	1.40	1.62	1.47	1.58	1.39
1967	1.50	1.70	1.52	1.65	1.48
1968	1.54	1.72	1.59	1.66	1.46
1969	1.52	1.81	1.64	1.66	1.49
1970	1.47	1.96	1.77	NA	1.50
1971	1.33	2.16	1.81	NA	1.46
1972	1.35	2.13	1.81	1.48	1.44
1973	1.30	2.01	1.85	NA	1.43
1974	1.36	2.07	1.91	NA	1.49
1975	1.39	2.19	1.89	1.39	1.50
1976	1.38	2.09	1.88	NA	1.50
1977	1.38	2.14	1.87	NA	1.52
1978	1.35	2.15	NA	1.47	1.54
1979 (prelim.)	NA	2.18	NA	NA	1.57
1980 (est.)	NA	NA	NA	NA	1.63
1981 (est.)	NA	NA	NA	NA	1.66
	Estimated civilian R&D expenditures[2] (national currency in billions)				
1961	3.2	NA	272.8	0.41	6.30
1962	3.8	4.1	316.5	NA	6.93
1963	4.6	4.8	365.2	NA	7.68
1964	6.1	5.8	434.7	.50	8.30
1965	6.7	7.0	504.5	NA	9.22
1966	7.4	7.9	571.6	.61	10.49
1967	8.6	8.4	695.8	.70	11.80
1968	9.7	9.2	868.9	.73	12.79
1969	11.0	10.8	1,055.4	.78	14.10
1970	11.5	13.3	1,333.3	NA	14.80
1971	12.0	16.3	1,508.0	NA	15.73
1972	13.6	17.6	1,758.0	.95	17.06
1973	14.6	18.5	2,173.2	NA	19.01
1974	17.5	20.4	2,655.4	NA	21.33
1975	20.2	22.7	2,892.5	1.45	23.21
1976	23.2	23.5	3.225.5	NA	25.70
1977	26.0	25.6	3,565.1	NA	29.19
1978	28.9	28.2	NA	2.38	33.28
1979 (prelim.)	NA	30.4	NA	NA	37.95
1980 (est.)	NA	NA	NA	NA	42.79
1981 (est.)	NA	NA	NA	NA	48.35

(continued)

Table 1-4. (Continued)

Year	France	West Germany	Japan	United Kingdom	United States
	Gross national product (national currency in billions)				
1961	328.4	333.0	19,852.8	27.5	524.6
1962	367.2	360.5	21,659.5	28.9	565.0
1963	412.0	382.1	25,592.1	30.8	596.7
1964	456.7	419.6	29,661.9	33.5	637.7
1965	489.8	458.2	32,981.6	36.0	691.1
1966	532.0	487.4	38,872.8	38.4	756.0
1967	574.8	493.7	45,896.8	40.5	799.6
1968	630.0	535.2	54,576.8	43.8	873.4
1969	734.0	597.7	64,513.6	47.1	944.0
1970	783.6	679.0	75,523.9	51.6	992.7
1971	873.1	756.0	83,166.0	57.8	1,077.6
1972	961.3	827.2	96,883.1	63.8	1,185.9
1973	1,121.3	920.1	117,257.9	74.1	1,326.4
1974	1,284.4	896.9	139,219.3	84.0	1,434.2
1975	1,455.2	1,034.9	153,126.3	104.7	1,549.2
1976	1,677.8	1,125.0	171,735.6	124.6	1,718.0
1977	1,881.8	1,197.2	190,426.3	142.3	1,918.0
1978	2,135.1	1,287.5	209,248.2	162.5	2,156.1
1979 (prelim.)	NA	1,393.8	NA	NA	2,413.9
1980 (est.)	NA	NA	NA	NA	2,626.1
1981 (est.)	NA	NA	NA	NA	2,920.0

[1] National expenditures for R&D, excluding Government funds for defense and space.

[2] Gross expenditures for performance of R&D including associated capital expenditures, except for the United States, where total capital expenditure data are not available.

NA = Not available

NOTE: The latest data from these sources may be preliminary or estimates.

SOURCES: Calculated from Appendix table 1-3 and data from country sources listed there and Organisation for Economic Co-operation and Development, *Changing Priorities for Government R&D* (Paris: OECD, 1975), and OECD *International Survey of the Resources Devoted to R&D by Member Countries, International Statistical Year — 1973: The Objectives of Government R&D Funding 1970-76* Vol. 2B (Paris: OECD, 1977), and National Science Foundation unpublished statistics.

See figure 1-4.

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Senator **Hawkins**. Thank you. I hope Senator Hatch explained to you that we are all interested and we all have statements for the record. We all submit them in the record. We are all members of too many committees is what happens but we do meet when you all are not watching and get together.

Thank you so much.

[Whereupon, at 12:25 p.m., the committee recessed, to reconvene at the call of the Chair.]

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